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Report on the Workshop Examining the Potential Effects of Hydroelectric Development on Beluga of the Nelson River Estuary, Winnipeg, Manitoba, November 6 and 7, 1990

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REPORT ON THE WORKSHOP EXAMINING THE POTENTIAL EFFECTS OF HYDROELECTRIC DEVELOPMENT ON BELUGA OF THE NELSON RIVER ESTUARY, WINNIPEG, MANITOBA, NOVEMBER 6 AND 7, 1990

by

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The contents of this report summarize the opinions of the workshop participants and do not necessarily reflect the views of the authors, Manitoba Hydro, or the Canada Department of Fisheries and Oceans.

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ABSTRACT

Lawrence, M.J., M. Paterson, R.F. Baker, and R. Schmidt. 1992. Report on the workshop examining the potential effects of hydroelectric development on beluga of the Nelson River estuary, Winnipeg, Manitoba, November 6 and 7, 1990. Can. Tech. Rep. Fish. Aquat. Sci. 1838: iv + 39 p.

This report summarizes the discussions and conclusions of a workshop held to examine the potential effects of hydroelectric development on beluga whales of the Nelson River estuary. Part I provides background information on the Nelson River estuary, beluga whales, and hydroelectric development on the Nelson River. Part II summarizes workshop assessments of the potential impacts of hydroelectric development on beluga whales in the Nelson River estuary. Recommendations for future research and monitoring programs are presented in Part III. Part IV provides an overall summary and general conclusions of the workshop.

Key words: beluga; Delphinapterus leucas; white whales; Hudson Bay; habitat.

RÉSUMÉ

Lawrence, M.J., M. Paterson, R.F. Baker, and R. Schmidt. 1992. Report on the workshop examining the potential effects of hydroelectric development on beluga of the Nelson River estuary, Winnipeg, Manitoba, November 6 and 7, 1990. Can. Tech. Rep. Fish. Aquat. Sci. 1838: iv + 39 p.

Dans le présent rapport, on résume les discussions et les conclusions de l'atelier sur les effets de l'aménagement de barrages hydroélectriques sur les bélugas de l'estuaire du fleuve Nelson. La Partie I fournit de l'information générale sur l'estuaire du fleuve Nelson, sur les bélugas, et sur l'aménagement de barrages hydroélectriques sur le fleuve Nelson. La Partie II donne un résumé des évaluations faites au cours de l'atelier sur les effets possibles de l'aménagement de barrages hydroélectriques sur les bélugas de l'estuaire du fleuve Nelson. Les recommandations relatives aux futurs programmes de recherche et de surveillance sont présentées dans la Partie III et on trouve dans la Partie IV un sommaire et les conclusions générales de l'atelier.

Mots clés: béluga; Delphinapterus leucas; Baie d'Hudson; habitat.

INTRODUCTION

Beluga (Delphinapterus leucas) are a small whale of arctic and subarctic waters. One of the largest concentrations of beluga whales is found in the estuary of the Nelson River in Hudson Bay. Recent studies suggest that at least 23,000 beluga live in western Hudson Bay, with up to 19,500 whales present within 145 miles of the Nelson estuary in summer (Richard et al. 1990). Despite the abundance of whales in this region, very little is known about their biology.

Beginning in 1961, a series of hydroelectric generating stations have been developed on the Nelson River. In 1976, 75% of the flow of the Churchill River was diverted into the Nelson through the Rat-Burntwood rivers. The most recently planned development is the Conawapa Generating Station (G.S.). Should the project receive environmental approval, the G.S. is tentatively scheduled to begin operation in 2000/2001.

On November 6 and 7, 1990, a workshop organized by Manitoba Hydro and the Canadian Department of Fisheries and Oceans brought together experts on beluga whales, the Nelson River estuary, and hydroelectric development. The workshop had three main objectives:

1) To assemble information on the ecology of beluga whales in the Nelson River estuary.

2) To assess the potential effects that changes to the Nelson River, associated with hydroelectric development (particularly the Conawapa G.S.), could have on the distribution, numbers, and health of beluga whales in western Hudson Bay.

3) To identify and recommend to the Department of Fisheries and Oceans, research and monitoring activities that are considered necessary for the identification and management of the effects of Nelson River hydroelectric development on beluga whales.

PART I. BACKGROUND

Background information on the Nelson River estuary and on beluga whales was provided in a discussion paper sent to all participants (Appendix 1) and in a series of talks presented on the morning of November 6. An agenda of talks, and a list of workshop participants is provided in Appendix 2. Working group rapporteur reports are presented in Appendix 3. A brief summary of information presented in the discussion paper and in subsequent talks is provided below.

1. PHYSICAL DESCRIPTION OF THE NELSON ESTUARY

- R.Baker (North/South Consultants Inc.)

A physical, chemical, and biological survey of the Nelson River estuary was undertaken by Baker (1989). The Nelson River estuary (Figure 1) is characterized by shallow water (generally less than 10 m) and high tides (up to 4.5 m). Extensive mudflats are exposed at low tide and a narrow (1 km wide) and deep (5-8 m) central channel cuts through these flats. The fluted shape of the estuary, variable river discharges, and the influence of the Coreolis Force act to produce complex hydrodynamics. Four physical zones, each with progressive distance from shore, have been described for the estuary: 1) a freshwater/riverine zone, influenced by tides, that extends from North Seal Creek for up to 10 km offshore of Port Nelson; 2) a nearshore estuarine zone characterized by low salinities (0-8 ppt), shallow water (0-5 m), and complete mixing; 3) a narrow stratified zone with moderate salinities (9-19 ppt); and 4) a large offshore zone characterized by moderately high salinities (>18 ppt), low temperatures, complete vertical mixing, and depths in excess of 5 m. This zone extends to the marine waters of Hudson Bay. The size and location of each zone varies with the tidal cycle, river discharge, and other factors. The result is an environment where salinities, temperatures, flow rates, and depth are continually changing.

2. BELUGA WHALES IN THE NELSON RIVER ESTUARY

- P. Richard (DFO)

The beluga whale population in western Hudson Bay is distributed in July between Arviat and James Bay. Whales are more or less continuously distributed along the coast during summer, with major concentrations in the Seal, Churchill, and Nelson River estuaries. Some doubt exists as to the genetic integrity of the western Hudson Bay stock and smaller stocks that inhabit northern Hudson Bay, Hudson Strait, and Ungava Bay (see review by Richard et al. 1990).

Beluga whales are highly mobile. They undertake long seasonal migrations and frequently inhabit estuaries in the spring and summer. There is preliminary evidence that some beluga whales have a strong fidelity for particular estuaries (see review by Richard et al. 1990). Beluga first arrive in the Nelson River estuary in May (Reeves and Mitchell 1989), with large numbers remaining through July and early August. Most whales leave by mid to late August (Baker 1989; Richard et al. 1990) and begin a northward migration along the western coast of Hudson Bay to wintering grounds in Hudson Strait (Finley et al. 1982). Within the Nelson River estuary, beluga regularly move onshore and offshore in response to tidal movements (Baker 1989). Beluga feed primarily on fish and large invertebrates (Comeau 1915; Doan and Douglas 1953; Sergeant 1962, 1973; Watts and Draper 1986).

3. BELUGA WHALES AND THEIR USE OF ARCTIC AND SUB-ARCTIC ESTUARIES

- T. Smith (DFO) and D. St. Aubin (University of Guelph)

It is unclear why beluga move to estuaries in summer. Some explanations have included:

1) Thermodynamics: Because estuaries are warmer than the open ocean, a greater proportion of energy can be directed towards growth.

2) Nursery grounds: Calves born between April and June may benefit from the warm, productive waters of the estuary (Sergeant 1973). However, studies of beluga body fat reserves suggest that young animals do not require warm water for effective thermal regulation. Most beluga births apparently occur in cold, offshore waters (Norton and Harwood 1985). Adult males, juveniles, and females with older calves also enter estuaries, further suggesting that these areas are not used exclusively as nursery grounds.

3) Molting and shedding of old skin: Beluga whales typically shed old skin while they inhabit estuaries. Possibly, increases in water temperature stimulate the secretion of thyroid hormones that promote molting and growth (St. Aubin and Geraci 1989, St. Aubin et al. 1990).

4) Social functions: Beluga whales undertake many complex social interactions in estuaries. The importance and function of these interactions is not known.

5) Feeding: Movement of beluga into estuaries is not believed to be associated with feeding. Stomachs of whales collected from estuaries typically contain few prey items (Sergeant 1973; Fraker et al. 1979).

4. HYDROELECTRIC DEVELOPMENT ON THE NELSON RIVER

- D. Windsor (Manitoba Hydro)

The Nelson and Churchill rivers collectively drain over 1.4 million km^2 of the interior plains of north-central America before flowing northeasterly into Hudson Bay (Figure 1). The first hydroelectric development on the Nelson River was the Kelsey G.S., built in 1961 to supply electrical power to a nickel refinery in Thompson, Manitoba. In 1970, a generating station on the Lower Nelson was completed at Kettle Rapids, forming Stephen's Lake in the process. Completion of the Jenpeg facility on the Upper Nelson in 1976, allowed the utilization of Lake Winnipeg as a large reservoir and the control of discharge of the Nelson River. In the same year, 75% of the flow of the Churchill River was diverted into the Nelson River through the Rat and Burntwood rivers. The Long Spruce and Limestone Generating stations on the Lower Nelson began operations in 1977 and 1990 respectively. The proposed Conawapa G.S. is scheduled to begin generation in 2000/2001.

The Nelson River has an annual average discharge of 2700 m^3sec^{-1}, of which approximately 750 m^3sec^{-1} is contributed by the Churchill River diversion. Prior to Lake Winnipeg regulation and Churchill River diversion, the Lower Nelson River had an annual flow regime characterized by high spring floods (3380 m^3sec^{-1}), reduced summer (3200 m^3sec^{-1}) and fall discharge (2900 m^3sec^{-1}), and low winter flows (1850 m^3sec^{-1}). With hydroelectric development, regulation of discharge is controlled by the Kettle G.S. The Limestone, Long Spruce, and proposed Conawapa facilities each have small reservoirs and are "run-of-the-river" stations. Typically, there is low discharge at night and increased discharge during the day (especially late afternoon and early evening). Within a day, mean hourly discharges may vary by as much as from 700 to 4950 m^3sec^{-1}. Total discharge during weekends is reduced from that on weekdays and average daily discharge is considerably higher in winter than in summer.

PART II. ASSESSMENT OF THE POTENTIAL IMPACT OF HYDROELECTRIC DEVELOPMENT ON BELUGA WHALES IN THE NELSON RIVER ESTUARY

1. THE ASSESSMENT PROCESS

The potential impact of hydroelectric development on beluga whales in the Nelson River estuary was assessed using a technique based on Duval et al. (1984). Because of time constraints, workshop participants agreed to concentrate primarily on the potential impact of development at Conawapa. The assessment was conducted in several steps:

a) Potential disturbances to the Nelson River estuary related to hydroelectric development were identified (Appendix 3, Table 1).

b) Potential paths of interaction linking beluga whales and the disturbances identified in step a) were described (Appendix 3, Table 2).

c) Project-beluga interactions (effects) were subsequently discussed and evaluated in three separate working groups. The potential importance of different impacts on beluga whales were evaluated. Where possible, spatial and temporal overlaps between potential disturbances and beluga whale populations were also examined (Appendix 3, Tables 3 - 7).

d) The rationale for all decisions and conclusions was recorded in an "audit trail".

2. POTENTIAL DISTURBANCES TO THE NELSON RIVER ESTUARY

Several disturbances of hydroelectric development on Nelson River hydrology with resulting potential for effects on the estuary were identified:

a) Changes in water temperature: The construction of reservoirs has probably affected water temperatures in the Nelson River. Because historical data are lacking, these changes are difficult to characterize. Experience from other rivers suggests that there may be an overall reduction in the amplitude of the annual temperature cycle (Baxter and Glaude 1980). It is uncertain how changes in the temperature of the Nelson River will affect or have affected temperatures in the Nelson estuary. Reductions in summer discharges may result in compression of the zone of nearshore warm water.

b) Changes in sedimentation: The formation of reservoirs has resulted in increased sediment loads to the Nelson River (e.g. Hecky and McCullough 1984). Coarse material probably settles within the reservoirs, whereas fine material is transported downstream. Because relatively small areas of shoreline will be flooded, workshop participants did not anticipate large increases in sedimentation in the Nelson estuary with hydroelectric development at Conawapa. The Department of Fisheries and Oceans is currently developing sediment budgets for the Nelson River (Greg McCullough, pers. comm.).

c) Changes in river discharge: The diversion of the Churchill River into the Nelson River has increased overall discharge to the Nelson estuary. Because of the prevalence of drought conditions, however, annual mean flows have yet to greatly exceed historic levels (D. Windsor, pers.comm.). Operation of generating stations on the Nelson River also alters seasonal discharge patterns. There is a net reduction of discharge during summer and a net increase in winter. Water levels, temperatures, salinity, and many other physical-chemical parameters in the Nelson estuary could be affected by changes in discharge. Long-term data are required to fully assess these influences.

Changes associated with construction of the Conawapa G.S. will probably be small relative to larger effects associated with initial hydroelectric development on the Nelson River. Although variations in discharge may be slightly more pronounced than in the past, they will probably be masked in the estuary by high tides. Workshop participants felt that only a narrow band of water at the interface of the riverine and estuarine zones would be affected by changes in discharge associated with Conawapa.

d) Changes in water chemistry: The results of field surveys suggest that only small changes in water chemistry have occurred with hydroelectric development on the Nelson River (Duncan and Williamson 1988). There were some concerns that mercury concentrations may increase and accumulate in fish and other organisms (cf. Bodaly et al. 1984). Because only 10 km^2 of shoreline will be flooded, large increases in mercury are not expected to occur with development at Conawapa.

e) Blockage of waterflows: The construction of dams on the Nelson River may prevent the upstream movement of diadromous fish populations.

f) Increased access to the Nelson River estuary: The construction of a road to the Conawapa G.S. site, and the up to 1500 workers associated with the construction of the Conawapa G.S., may result in increased traffic to the estuary.

3. POTENTIAL IMPACTS OF HYDROELECTRIC DEVELOPMENT ON BELUGA WHALES IN THE NELSON RIVER ESTUARY

Three general classes of interactions linking beluga whales and potential disturbances were examined: 1) direct effects of changes in physical-chemical conditions; 2) indirect effects of disturbances mediated through the food web; and 3) effects of hydroelectric development on socioeconomic conditions that may affect beluga whales (and to a lesser extent, effects on beluga whales that may affect socio-economic conditions). Specific paths of interaction and the importance of various impacts were evaluated for each class of interactions by a different working group. Summaries of discussions are presented in Appendix 3. The members of each working group are listed in Appendix 2. Participants in the working groups on indirect and socioeconomic effects concentrated almost exclusively on the potential impact of the Conawapa G.S. Members of the working group on direct effects took a more general approach and discussed the potential impact of hydroelectric developments on estuarine populations of beluga whales.

3.1. Direct effects

Potential impacts on beluga whales of changes in physical-chemical conditions associated with hydroelectric development were examined. Only the effects of changes in temperature and discharge were considered in detail. Other impacts were primarily expected to affect beluga through changes in the food web (indirect effects working group).

a) Temperature: Large gaps in existing knowledge made it impossible for workshop participants to accurately predict the effects of changes in water temperature on beluga whales. It is unclear whether temperature patterns in the Nelson estuary have been or will be markedly affected by hydroelectric development. There is also little information concerning the effects of water temperature on

beluga whale behaviour and physiology. In general, it was felt that changes in temperature associated with Conawapa were likely to be small and within the adaptive capabilities of beluga whales. Only speculative guesses about potential impacts could be made.

It is unclear why beluga whales move to estuaries in summer. Declines in estuarine water temperatures caused by low summer discharge could be important, if migrations are undertaken to gain thermal advantage from estuaries. For example, the entry of beluga whales into estuaries is associated with elevated production of thyroid hormones that may enhance growth and molting (St. Aubin and Geraci 1989). Increased hormone secretion is more closely correlated with temperature than other factors such as photoperiod, diet, or time of day. As a result, changes in temperature patterns in the Nelson estuary may affect molting. Changes in water temperature may also affect other behavioral and physiological processes. Unfortunately, lack of data makes such suggestions highly tenuous. More research is clearly required.

It was also speculated that changes in seasonal temperature patterns may affect the movement of whales to and from the Nelson estuary. Whales apparently move into the estuary as soon as clear channels are open through the ice in spring. Although the effect of hydroelectric development on ice regimes is unclear, delays in the timing of spring breakup could potentially affect access of whales into the estuary.

Increased discharges in late summer could delay the cooling of waters in the Nelson River estuary. Participants felt that these delays were unlikely to affect the autumn migration of whales. Studies in the Mackenzie River indicated that beluga whales left the estuary before any large degree of water cooling (Fraker et al. 1979). The daily inshore-offshore movements of beluga also result in exposure to a wide range of water temperatures, suggesting that other factors are important in the initiation of autumn migrations.

b) River discharge: Alterations of discharge patterns with hydroelectric development potentially affect a wide variety of parameters in estuaries including water temperature (discussed above), salinity, water depth, flow rates, etc. For example, low discharges during periods of flood tides may increase salinities in nearshore waters, relative to pre-development conditions. Similarly, combinations of low tides and high discharges will push fresh water further offshore. Because of complex hydrologic conditions in the Nelson River estuary, the exact nature of any impacts are uncertain. Only small changes in discharge patterns are expected with construction of the Conawapa G.S.

The effects of changes in discharge on beluga whales are difficult to evaluate. In general, beluga do not seem to be strongly affected in the short term by changes in salinity, flow rates, temperature, etc., but the effects of simultaneous changes in many parameters cannot be ignored. There is some suggestion that low salinity may aid molting in beluga whales (St. Aubin et al. 1990). As a result, increases in salinity associated with low discharge could potentially affect molting activity.

Occasionally, beluga whales may become stranded on tidal flats (e.g. Heyland and Hay 1976; Bruemmer 1986; Watts and Draper 1988). Workshop participants expressed concern that combinations of low discharges and extremely low tides may increase strandings. It was agreed that this was likely to have only a minor impact on beluga populations. Stranding is an infrequent event and stranded whales usually escape on the next high tide (T. Smith, pers.comm.). It should be noted, however, that stranded whales are vulnerable to predation by polar bears and may suffer organ damage. It may be possible to minimize the impact of river regulation by ensuring that periods of extremely low discharge and low tides do not coincide.

3.2. Indirect effects

Potential effects of hydroelectric development at Conawapa on food resources of beluga whales were examined. Changes in the availability of food may have important effects on beluga population dynamics.

Beluga whales are opportunistic feeders on fish and invertebrates. In estuaries of western Hudson Bay, beluga whales have been documented to feed on capelin, lake whitefish, cisco, pike, suckers, and arctic char (Comeau 1915; Doan and Douglas 1953; Sergeant 1962, 1973; Watts and Draper 1986). A variety of invertebrate remains have also been encountered in beluga stomachs including squid, polychaetes, and decapods (Doan and Douglas 1953; Sergeant 1962, 1973). Several authors have remarked on the presence of stones and mud in beluga stomachs, suggesting that they frequently feed near the bottom. Young beluga after weaning feed largely on benthic crustaceans (Sergeant 1962). With movement of beluga whales to northern waters, the diet may shift to include increasing numbers of crustacea, cod, and char (Sergeant 1973).

Most workshop participants felt that the annual energy budget of beluga whales does not rely heavily on food from estuaries. Stomachs of beluga from estuaries typically contain few prey (Sergeant 1973; Fraker et al. 1979) and the percentage of empty stomachs decreases with fall migrations (Sergeant 1973). This suggests that beluga whales do not enter estuaries for feeding purposes and that feeding is primarily a maintenance activity. Digestion in beluga whales is rapid (Doan and Douglas 1953) and absence of food in whale stomachs may be an artifact caused by delays between feeding and sampling (P. Richard, pers. comm.). More research is required.

To simplify discussions, workshop participants focused on the

potential impacts of hydroelectric development on three groups of organisms of importance to beluga whales: benthic invertebrates, capelin, and lake whitefish. Hereafter, these are collectively referred to as "Valued Food Components" (VFCs). Invertebrates were selected because they are food for both beluga whales and their fish prey (Baker 1989). Capelin were selected as a representative marine fish. They are common in the diet of beluga whales and are probably abundant in the offshore estuarine zone of the Nelson River estuary. Capelin primarily inhabit cold, offshore waters, but move inshore in summer to spawn on beaches (Scott and Scott 1988). Capelin feed on planktonic invertebrates including copepods, amphipods, and euphausids (Scott and Scott 1988).

Lake whitefish were the most abundant diadromous fish in surveys of the Nelson River estuary undertaken by Baker (1989, 1990). The life history of lake whitefish in this area is not yet completely known, but is probably similar to that of populations in eastern Hudson Bay. In the LaGrande and Eastmain rivers, mature whitefish move upriver in fall and spawn in mid-October (Morin and Dodson 1986). Eggs overwinter, hatch with the spring thaw and larvae are passively carried downstream into the Hudson Bay. Juvenile fish live in coastal regions during summer and usually move to riverine habitats in September and October, where they pass the winter (Morin et al. 1981). The life history of cisco, another abundant diadromous fish in the Nelson River estuary, is probably similar (Morin and Dodson 1986). Whitefish in the Nelson River estuary feed on a variety of invertebrates including insects, Mysis, and molluscs (Baker 1989).

a) Temperature: The effects of hydroelectric development on temperature patterns in the Nelson River estuary are unclear and workshop participants could only speculate on potential impacts on VFCs. Participants felt that changes in temperature patterns would have little impact on capelin, but may affect whitefish and invertebrates. In general, overall impacts were expected to be small (less than 10% of the population affected).

b) Sedimentation: Of the VFCs, filter-feeding benthic invertebrates are most sensitive to changes in sedimentation patterns. If invertebrates are strongly affected, indirect impacts on whitefish and beluga whales may result. Large increases in sedimentation in the Nelson estuary are not expected with construction of the Conawapa G.S. As a result, large impacts on the fauna of the estuary are unlikely.

c) River discharge: The effects of potential changes in river discharge were also difficult to evaluate. Shifts in spatial and temporal fluctuations in water depth and salinity may affect benthic productivity and, in turn, fish populations.

Benthic invertebrates in the estuary probably rely on carbon and nutrients transported down the Nelson River. Changes in the availability of these resources are potentially important, but difficult to quantify. Overall impacts on VFCs were expected to be small (less than 10% of the populations would be affected).

d) Water chemistry: Construction of the Conawapa G.S. is not expected to cause large changes in water chemistry. Flooding of South Indian Lake in northern Manitoba led to increased concentrations of mercury in fish (Bodaly et al.1984), and there were concerns that similar increases may occur in the Nelson River and estuary. Mercury tends to accumulate most in organisms higher in the food chain and, consequently, beluga whales may be particularly susceptible. Because only 10 km^2 of shoreline will be flooded by Conawapa, large increases in mercury levels in fish and other organisms are not expected.

e) Blockage of water flow: The Conawapa G.S. will prevent the movement of diadromous fish to upstream spawning sites. Recent research has documented the likelihood of spawning habitats for lake cisco above Conawapa (MacDonell 1991). The location of spawning sites of lake whitefish are not known. The importance of upstream habitats to diadromous fish population dynamics is uncertain, but in the worst case could result in elimination of lake whitefish populations. Lake cisco and brook trout may be less likely to be affected by river blockage as they utilize alternative tributaries for spawning. Because the importance of diadromous fish to beluga is unknown, the indirect effect of reductions in fish populations remains uncertain.

3.3. Socioeconomic effects

The working group on socioeconomic effects examined the potential impact of increased human activity in the Nelson River estuary on beluga whales. Two sets of linkages between the Conawapa Project, beluga whales and local socioeconomic conditions were postulated as models to guide the examination of the potential effects of the project:

1) Conawapa Project ——▸ Changes to Nelson River ——▸ Biophysical Changes ——▸ Change in the Opportunity for both Consumptive and non-Consumptive use of the whales ——▸ Change in Local Economy and Community Values; and

2) Conawapa Project ——▸ Improved and Increased Access to the Estuary ——▸ Increased Consumptive and non-Consumptive use of the Whales and Disruption to the Estuarine Community ——▸ Change in Local Economy and Community Values.

Three main areas of activity were examined: 1) increased tourism activities in and around the estuary; 2) increased hunting of whales; and 3) increased domestic fishing by native bands.

a) Tourism: The presence of an access road and up to 1500 workers during the construction phase of the Conawapa

G.S. may increase tourism to the Nelson River estuary. The Conawapa development will also flood the Lower Limestone Rapids and make the estuary somewhat more accessible by boats. Workshop participants speculated that this could lead to increased harassment of whales.

Beluga whales appear to have a high threshold for disturbance, but the effects of the resultant increase in stress are unknown. Although beluga move away from estuaries in response to noise from small boat engines or low-flying aircraft, they usually return within a few hours (Finley et al. 1982; Caron and Smith 1990). Beluga also continue to use estuaries despite sustained harassment such as hunting (Caron and Smith 1990).

In general, workshop participants felt that development at Conawapa was unlikely to cause much increase in whale-watching activity. The turbid waters and large size of the Nelson estuary may discourage low-level flights to observe whales. Turbid waters and strong currents will also restrict SCUBA diving among whales. Boat traffic is expected to increase but will probably remain below harmful levels.

Several strategies were suggested to minimize tourist impacts on whales. Workers and the general public should be educated about the effects of whale harassment and about ways to minimize disturbance effects. Regulators and Manitoba Hydro must keep workers at Conawapa informed of regulations and enforcement of guidelines is required. Present jurisdictional responsibilities with respect to licencing and control of Manitoba tour operations involving a federally managed resource are unclear and should be clarified. Tour operators could be licensed and required to adhere to codes of conduct.

b) Hunting: At present, there is no whale hunting in the Nelson River estuary. In Canada, hunting of beluga whales is primarily restricted to native Indians and Inuit. If Inuit from Rankin Inlet or other communities in the Northwest Territories were employed at Conawapa they may wish to hunt beluga whales in the Nelson estuary. Were this to happen, it is unlikely that they would take large numbers of whales because of difficulties in travelling to the estuary and in storing their harvest.

c) Domestic fishing: At present, there is little or no fishing in the Nelson River estuary. It was speculated that improved access might lead to increased interest in domestic gillnet fishing by native bands. Whales may occasionally become entangled in gillnets and, possibly, increased fishing could cause declines of fish used as food by belugas.

In general, it is unlikely that development at Conawapa will result in greatly elevated fishing effort. In the Nelson River estuary, catch per unit effort is low and fishing is dangerous and expensive (Baker 1989). Any increases in fishing effort are anticipated to occur in the lower Nelson River or its tributaries (e.g. Angling River, Weir River), where some domestic fishing already takes place. Increased fishing in these areas could potentially affect diadromous fish populations potentially utilized by beluga.

Whales and fish in the Nelson River estuary may become protected by changes in future status. There are discussions about the development of a national park that might result in some restrictions on fishing and hunting activity in the Nelson estuary.

PART III. RECOMMENDATIONS FOR RESEARCH AND MONITORING ACTIVITIES

There is much to be learned about the biology of beluga whales in the Nelson River estuary and workshop participants identified several important areas for future research and monitoring (Appendix 3, Tables 8 - 10). There was general agreement that programs should not be restricted to the Nelson estuary and that cumulative effects of hydroelectric development in the greater Hudson Bay should be considered. Although impact studies in separate estuaries may suggest minimal effects on local whale populations, the combined effects of developments in several estuaries may be important to beluga population dynamics.

1. DIRECT IMPACTS

There are many uncertainties about how physical-chemical conditions in the Nelson estuary are being affected by hydroelectric development. Additionally, there is a need to determine how changes in physical-chemical conditions affect beluga whales. Because whales are highly adaptable, changes in single physical-chemical parameters may not cause easily detectable changes in behaviour. Simultaneous changes in many parameters, however, may interact in complex ways to affect beluga.

Most participants felt that the behaviour of whales could be studied most easily using telemetry. Sensor systems attached to whales could establish where and when whales moved and could provide basic information on water temperatures, depth, etc. Sex-specific and age-specific behaviour should be examined. Data on whale movements could then be compared with information about physical-chemical conditions.

It may be possible to obtain physical-chemical data for the Nelson River and estuary from several sources. Manitoba Hydro is preparing a hydrologic model for the Nelson River and data from this model can be used a) to determine and monitor flood/drawdown conditions for any flow regime and b) to estimate heat budgets for the Nelson River and estuary. Hydrologic data will be made available to researchers on a cooperative basis. Manitoba Hydro may also install sampling/recording platforms to collect data on physical-chemical

conditions (e.g. temperature, salinity, etc.) in the Nelson River and estuary. Further information on some physical-chemical parameters (e.g. relative surface temperature, turbidity, ice cover) can be obtained from NOAA satellite imagery. Continuous monitoring of other estuaries in the Hudson Bay will help elucidate the effects of hydroelectric development on physical-chemical conditions.

Physiological studies would provide further information on the effects of changes in physical-chemical parameters on whales. One participant suggested following the movements of individual whales and taking repeated measurements of selected physiological variables. This approach would require several live-captures and would be labour-intensive. The physiological condition of any animals captured in whale-hunts should also be monitored.

The independent effects of different physical-chemical parameters could also be examined through laboratory tests. Unfortunately, the stress of captivity complicates experiments and makes results difficult to apply to natural populations.

Most participants agreed that aerial monitoring of belugas in the Nelson estuary would be of limited use. Confidence intervals associated with such surveys are large and few reliable conclusions concerning whale numbers and behaviour can be made. Mark-recapture techniques were also regarded to be of minimal value. The development of a long-retention tag would aid studies of the distribution and movement of whales.

Some belugas apparently have a strong fidelity for particular estuaries and based on preliminary studies, populations in different estuaries may be genetically distinct. To assess the effects of development in any one estuary, it is essential to know the extent of whale movement among estuaries. The examination of DNA markers in beluga whales throughout Hudson Bay would help identify different whale stocks, their locations, and stock integrity (e.g. Helbig et al. 1989). These data would also help determine the extent of genetic inter-change among populations.

In summary, workshop participants suggested a wide variety of studies to elucidate the direct effects of hydroelectric development on beluga whales in the Nelson estuary. It was agreed that telemetry studies of whale behaviour and DNA marking programs were of the highest priority.

2. INDIRECT IMPACTS

To assess the importance of potential indirect impacts, more information is required on beluga feeding habits. In particular, it is unclear how much beluga rely on food within the Nelson estuary and what contribution is made by diadromous and marine fish. Telemetry studies can provide information on dive times, depths, and the location of whales that may indirectly indicate feeding patterns. Information on the location of various food sources in relation to physical-chemical factors would aid the interpretation of telemetry data. Examinations of the stable isotope composition of beluga tissue (skin and muscle) and different potential food sources would provide data on the importance of different food sources. In particular, isotope studies could help determine the relative importance of food from freshwater and marine environments.

The development of hydrologic models of the Nelson estuary may help reconstruct recent changes in temperature, salinity, sedimentation, etc. These models would aid in the assessment of impacts of hydroelectric development on beluga food resources and help guide future research. Workshop participants also indicated that spawning grounds of diadromous fish must be located to determine the importance of river blockage by the Conawapa G.S. to fish populations.

3. SOCIOECONOMIC EFFECTS

Participants of the working group on socioeconomic effects agreed that air and boat traffic to the estuary should be monitored to determine changes in human use patterns with development at Conawapa. In particular, hunting and fishing activities in the Nelson River, estuary, and local tributaries should be followed. Additionally, monitoring of resource use by non-local aboriginal groups would provide indications of shifts in diet that may be related to improved access to beluga whales. Guidelines for whale-watching specific to the Nelson estuary should be developed to supplement the general whale watching guidelines that now apply.

Research should be undertaken to determine the effects of different types and intensities of disturbance on beluga behaviour. The ability of whales to habituate to different disturbances should also be examined. Small scale surveys may help determine how changes in human activity in the Nelson estuary affect whale distributions and behaviour. Impacts on beluga populations in other estuaries should also be examined to assess the potential effects of human activity on beluga population dynamics in Hudson Bay.

PART IV. SUMMARY

1. The Conawapa G.S. is not expected to strongly affect temperature regimes, sedimentation patterns, river discharge (and associated changes in salinity, water levels, etc.), and water chemistry in the Nelson River estuary. Access to fish habitat upstream of the generating station site will be restricted by Conawapa, and the presence of a road to the Conawapa site will improve human access to the estuary. Unfortunately, gaps in existing knowledge concerning the exact nature of development effects and the biology of beluga whales made assessments of potential impacts highly tenuous.

2. In general, workshop participants felt that changes in

physical-chemical conditions in the Nelson River estuary would not be large enough to strongly affect beluga whales. Changes in temperature regimes and salinity may affect the molting of old skin. There were also concerns that changes in temperature patterns and river discharge could influence the migrations of whales to and from the estuary. Combinations of low discharges and low tides may result in increased incidence of whale stranding. Although whales seem capable of adapting to changes in any single physical-chemical parameter, the combined effects of simultaneous changes in many parameters are unknown.

3. Workshop participants also felt that indirect impacts to beluga whales, mediated through the food web, would be small. Although more research is required, most participants felt that beluga do not rely heavily on food resources within the estuary. Among food were expected to be the most impacted by hydroelectric development. Blockage of the Nelson river by Conawapa may prevent these fish from reaching their spawning sites and, if not mitigated, could strongly affect their population numbers.

4. Development at Conawapa may lead to increased tourism, domestic fishing, and hunting of beluga whales in the Nelson River estuary. In general, workshop participants felt that these impacts would be small and could be further minimized through public education and the development and enforcement of guidelines.

5. The biology of beluga whales is poorly known and many areas were identified for future research and monitoring. Workshop participants urged that research and monitoring not be limited to the Nelson estuary. The overall population dynamics of beluga whales throughout Hudson Bay should be considered.

ACKNOWLEDGMENTS

We wish to thank all those who participated in the workshop sessions. Special thanks go to Dennis Windsor, Manitoba Hydro for his encouragement and support in getting the workshop underway, and Rob Stewart and Tom Strong of the Department of Fisheries and Oceans for guidance and advice in the planning of the workshop.

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REFERENCES

Baker, R.F. 1989. An environmental assessment and biological investigation of the Nelson River estuary. Report prepared for Manitoba Hydro by North/South Consultants Inc. 179 p.

Baker, R.F. 1990. A fisheries survey of the Nelson River estuary, August, 1989. A report prepared for Manitoba Hydro by North/South Consultants Inc. 27 p.

Baker, R.F. 1991. A fisheries survey of the Limestone forebay, 1990 - Year II. A report prepared for Manitoba Hydro by North/South Consultants Inc. 58 p.

Baxter, R.M., and P. Glaude. 1980. Environmental effects of dams and impoundments in Canada: experience and prospects. Can. Bull. Fish. Aquat. Sci. 205: 34.

Bodaly, R.A., R.E. Hecky, and R.J.P. Fudge. 1984. Increases in fish mercury levels in lakes flooded by the Churchill River diversion, northern Manitoba. Can. J. Fish. Aquat. Sci. 41: 682-691.

Breton-Provencher, M. 1979. Étude de la population de bélugas de la région de Poste-de-la-Baleine (Nouveau-Quebec). GIROQ, rapport à Hydro-Québec; projet Grande-Baleine (mandat OGB/76-1). 93 p.

Bruemmer, F. 1986. White whales on holiday. Nat. Hist. 95: 40-49.

Caron, L.M.J., and T.G. Smith. 1990. Philopatry and site tenacity of belugas, Delphinapterus leucas, hunted by the Inuit at the Nastapoka estuary, eastern Hudson Bay, p. 69-79. In T.G. Smith, D.J. St. Aubin and J.R. Geraci (ed.) Advances in research on the beluga whale, Delphinapterus leucas. Can. Bull. Fish. Aquat. Sci. 224.

Comeau, N. 1915. Report on the fisheries expedition to Hudson Bay in the auxiliary schooner "Burleigh" 1914. Department of Naval Service, Ottawa.

Doan, K.H., and C.W. Douglas. 1953. Beluga of the Churchill region of Hudson Bay. Bull. Fish. Res. Board Can. 98: 27 p.

Duncan, D.A., and D.A. Williamson. 1988. Water chemistry / water discharge relationships within the Churchill River diversion and Lake Winnipeg Regulation region, Manitoba, Canada. Manitoba Department of Environment and Workplace Safety and Health. Water Standards and Studies Report #87-8.

Duval, W.S., L.A. Harwood, L.C. Martin, and B. Smiley. 1984. A semi-quantitative method for preliminary assessment of environmental impacts. Unpublished report prepared for Institute of Ocean Sciences, Department of Fisheries and Oceans, Sydney, BC. 26 p.

Finley, K.J., G.W. Miller, M. Allard, R.A. Davis, and C.R. Evans. 1982. The belugas (Delphinapterus leucas) of northern Quebec: distribution, abundance, stock identity, catch history and management. Can. Tech. Rep. Fish. Aquat. Sci. 1123: 56 p.

Fraker, M.A., C.D. Gordon, J.W. McDonald, J.K.B. Ford, and G. Cambers. 1979. White whale (Delphinapterus leucas) distribution and abundance and the relationship to physical and chemical characteristics of the Mackenzie estuary. Can. Fish. Mar. Serv. Tech. Rep. 863: 56 p.

Hecky, R.E., and G.K. McCullough. 1984. Effect of impoundment and diversion on the sediment budget and nearshore sedimentation of Southern Indian Lake. Can. J. Fish. Aquat. Sci. 41: 567-578.

Helbig, R., P.T. Boag, and B.N. White. 1989. Stock identification of beluga whales (Delphinapterus leucas) using mitochondrial DNA markers: preliminary results. Musk-Ox 37: 122-127.

Heyland, J.D., and K. Hay. 1976. An attack by a polar bear on a juvenile beluga. Arctic 29: 56-57.

MacDonell, D.S. 1991. Enumeration and biological description of migrating fish in the Limestone River, Manitoba, 1990. A North/South Consultants Inc. report for Manitoba Hydro. 86 p.

Morin, R., and J.J. Dodson. 1986. The ecology of fishes in James Bay, Hudson Bay and Hudson Strait, p. 265-292. In I.P. Martini (ed.) Canadian inland seas. Elsevier, Amsterdam.

Morin, R., J.J. Dodson, and G. Power. 1981. The migration of anadromous cisco (Coregonus artedii) and lake whitefish (C. clupeaformis) in estuaries of eastern James Bay. Can. J. Zool. 59: 1600-1607.

Norton, P., and L.A. Harwood. 1985. White whale use of the southeastern Beaufort Sea, July-September 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1401: 46 p.

Parsons, T.R., D.G. Webb, B.E. Rokeby, M.J. Lawrence, G.E. Hopky, and D.B. Chiperzak. 1989. Autotrophic and heterotrophic production in the Mackenzie River-Beaufort Sea estuary. Polar Biol. 9: 261-266.

Parsons, T.R., D.G. Webb, H. Dovey, R. Haigh, M. Lawrence, and G.E. Hopky. 1988. Production studies in the Mackenzie River-Beaufort Sea estuary. Polar Biol. 8: 235-239.

Reeves, R.R., and E. Mitchell. 1989. History of exploitation, distribution and stock identity of white whales in Western Hudson Bay and Foxe Basin. Unpublished report to Department of Fisheries and Oceans. 202 p.

Richard, P.R., J.P. Orr, D.G. Barber. 1990. The distribution and abundance of belugas, Delphinapterus leucas, in eastern Canadian subarctic waters: a review and update, p. 23-38. In T.G. Smith, D.J. St. Aubin and J.R. Geraci (ed.) Advances in research on the beluga whale, Delphinapterus leucas. Can. Bull. Fish. Aquat. Sci. 224.

Scott, W.B., and M.G. Scott. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 730 p.

Sergeant, D.E. 1962. The biology and hunting of beluga or white whales in the Canadian Arctic. Fish. Res. Board Can. Arct. Unit, Montreal, Que. Circ. 8: 13 p.

Sergeant, D.E. 1973. Biology of white whales (Delphinapterus leucas) in western Hudson Bay. J. Fish. Res. Board Can. 30: 1065-1090.

Smith, T.G., and M.O. Hammill. 1986. Population esti mates of white whale, Delphinapterus leucas, in James Bay, eastern Hudson Bay, and Ungava Bay. Can. J. Fish. Aquat. Sci. 43: 1982-1987.

St. Aubin, D.J., and J.R. Geraci. 1989. Seasonal variation in thyroid morphology and secretion in the white whale, Delphinapterus leucas. Can. J. Zool. 67: 263-267.

St. Aubin, D.J., T.G. Smith, and J.R. Geraci. 1990. Seasonal epidermal molt in beluga whales, Delphinapterus leucas. Can. J. Zool. 68: 359-367.

Wagemann, R., R.E.A. Stewart, P. Beland, and C. Desjardins. 1990. Heavy metals and selenium in tissues of beluga whales, Delphinapterus leucas, from the Canadian Arctic and St. Lawrence estuary, p. 191-206. In T.G. Smith, D.J. St. Aubin and J.R. Geraci (ed.) Advances in research on the beluga whale, Delphinapterus leucas. Can. Bull. Fish. Aquat. Sci. 224.

Watts, P.D., and B.A. Draper. 1986. Note on the behaviour of beluga whales feeding on capelin. Arct. Alp. Res. 18: 439.

Watts, P.D., and B.A. Draper. 1988. Beluga whale ecology: a concern of freshwater biologists? Freshwat. Biol. 20: 211-213.

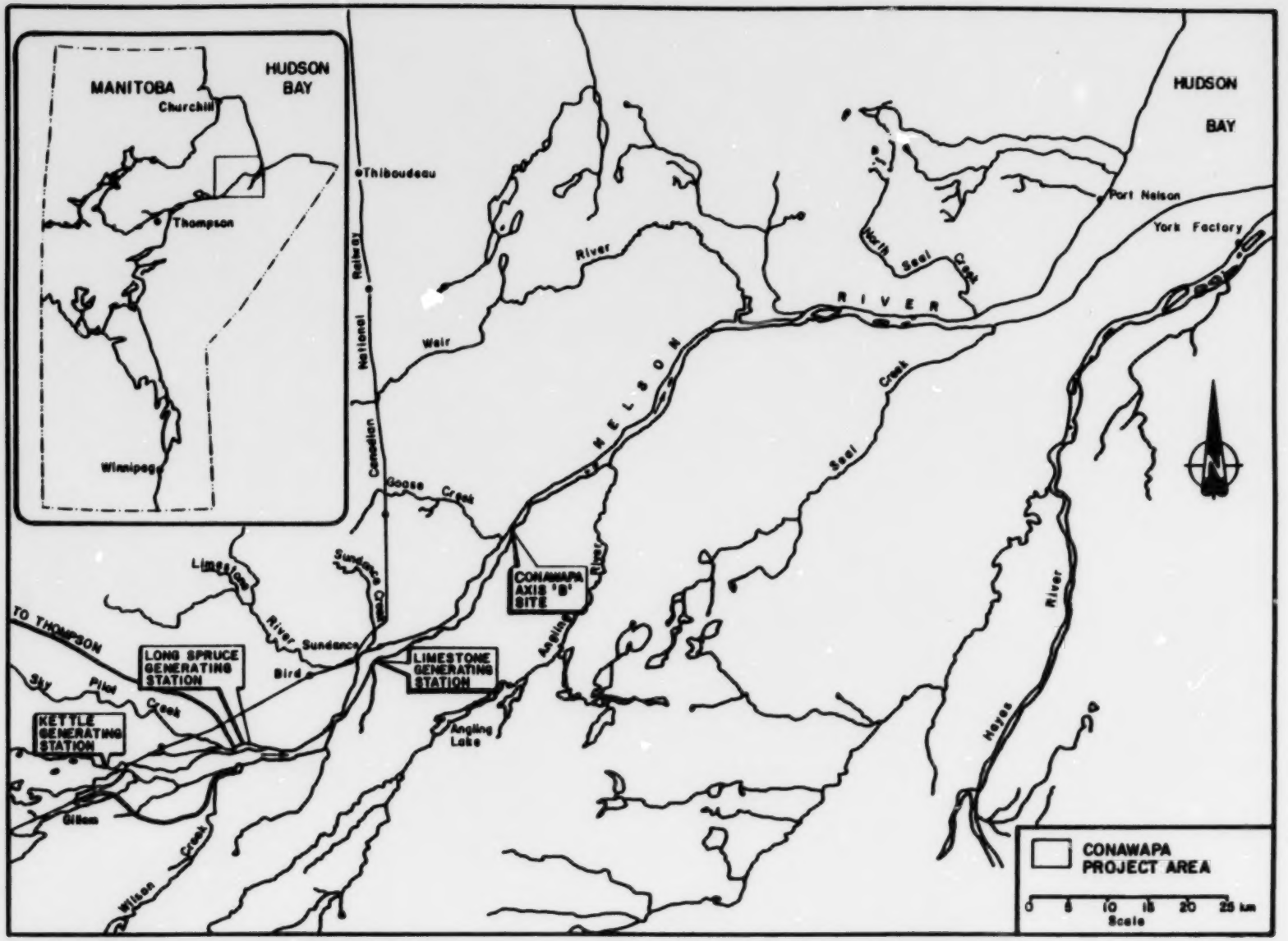

Figure 1. Map showing location of the lower Nelson River and estuary in relation to the Conawapa project Area, Manitoba.

APPENDIX 1 - Discussion Paper:
Nelson River Estuary - Beluga Whale Workshop

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This discussion paper is intended as a preparatory document for participants of the workshop concerning beluga whale of the Nelson River estuary. The workshop was conceived in response to a need to examine what is currently known about this population of whales and how they may be affected by hydroelectric development planned for the Nelson River.

In order to familiarize participants with relevant background information prior to the workshop, and to aid in its success, the following items are presented in a summary fashion.

1) A brief life history of western Hudson Bay beluga whale;
2) Pre- and post-regulation conditions of the Nelson River, including significant hydro-related events;
3) A brief description of the physical environment of the Nelson River estuary;
4) A list of potential impacts on the aquatic environment of the lower Nelson River and estuary, by hydroelectric development (this includes cumulative effects);
5) Discussion topics.

Life History

The western Hudson Bay (WHB) beluga population, of which the Nelson River estuary population is part, is distributed between Southampton Island and James Bay. Whales are more or less continuously distributed along the coast, up to 120 km offshore, with major concentrations in the Seal, Churchill and Nelson River estuaries. Some doubt exists as to the integrity of the WHB stock and smaller stocks which inhabit northern Hudson Bay, Hudson Strait and Ungava Bay. This is due to the common wintering ground each stock is believed to utilize.

The most recent study (P. Richard, Fisheries and Oceans, Winnipeg, pers. comm.) has estimated that at least 23,000 animals comprise the WHB stock, with up to 19,500 whales present within 145 km of the Nelson River estuary during summer. These whales are highly mobile, exhibiting short, daily onshore - offshore movements within estuaries and long, seasonal south - north (and north - south?) coastal migrations during the open water season. Within the Nelson River estuary, beluga regularly move onshore and offshore, primarily in response to tidal movements (Baker 1988). Beluga whales have been observed as far up river as Gillam Island. Whales are believed to arrive at the estuary during mid- to late June and remain in large numbers throughout July and early August, leaving the estuary by mid- to late August. During late September, 1990, however, a beluga whale was observed offshore of Port Nelson (Baker 1988).

WHB beluga whale are believed to feed on fish, primarily capelin and possibly lake whitefish, lake cisco and sucker in southern estuaries. A dietary shift towards decapod and gastropod invertebrates is thought to occur as whales move northward during summer, along the Keewatin coast.

Beluga whales are believed to inhabit arctic and sub-arctic estuaries during the summer, including, but not necessarily limited to the following:

- nursery grounds, that afford calves born between April and June, shelter and warmer waters in which to develop;
- feeding grounds, as estuaries are generally very productive environments;
- thermodynamics, in order that a greater proportion of energy can be devoted towards growth in warmer, estuarine water;
- molting and sloughing of old skin in shallow, fresh-water;
- shedding of marine parasites;
- social functions, where breeding pairs may form, stock mixing may occur, and social orders become established and strengthened;
- unknown social and/or behavioral motives.

No biological studies have been conducted on the Nelson River estuary beluga whale population, believed to be the largest single concentration of beluga in the world. Large information deficiencies in basic life history parameters such as movements, diet, age structure, growth, reproduction, etc. in general, exist for the WHB beluga whale population.

Pre- and Post-regulation Conditions

The Nelson and Churchill rivers collectively drain over 1.4 million km^2 of the interior plains of north-central America before flowing northeasterly into Hudson Bay. The Nelson River currently has an annual average discharge of 2770 $m^3 \cdot sec^{-1}$, of which approximately 750 $m^3 \cdot sec^{-1}$ is contributed by the Churchill River. Prior to watershed regulation, the Nelson River had an annual flow regime characterized by high spring floods (3380 $m^3 \cdot sec^{-1}$), followed by reduced summer (3200 $m^3 \cdot sec^{-1}$) and fall (2900 $m^3 \cdot sec^{-1}$) flows and low winter (1850 $m^3 \cdot sec^{-1}$) discharge. Subsequent to regulation, spring discharge values average 2650 $m^3 \cdot sec^{-1}$, 2350 $m^3 \cdot sec^{-1}$ during summer, 2400 $m^3 \cdot sec^{-1}$ during fall and 3260 $m^3 \cdot sec^{-1}$ during winter (based on 10 year seasonal averages). Average monthly values within and between seasons and years, vary considerably more than the values presented here.

The first hydroelectric development to occur on the Nelson River was the Kelsey Generating Station, built in 1961, to supply electrical power to a nickel refinery in Thompson, Manitoba. In 1970, the first of three > 1000 MW generating stations on the lower Nelson River was completed at Kettle rapids, forming Stephens Lake in the process. Regulation of Lake Winnipeg for use as a large reservoir was achieved in 1976, with completion of the Jenpeg facility. This develop-

ment allowed complete control of discharge of the Nelson River. Diversion of 75% of the flow of the Churchill River, through the Rat-Burntwood rivers, to augment flow of the Nelson River, was also accomplished in 1976. The Long Spruce (1977) and Limestone (1989) generating facilities, are the most recent hydroelectric development facilities on the Nelson River.

Regulation of downstream discharge rates and patterns are now entirely controlled by the Kelsey G.S. Each of the large facilities, Limestone, Long Spruce and Kettle, have small reservoirs and are considered "run-of-the-river" stations. These facilities, respond immediately to increases or decreases in power demand, consequently, discharge patterns mirror southern, consumer requirements for electrical power, which vary on an hourly, daily, weekly and seasonal basis. A typical daily scenario consists of the following pattern; low discharge during late evening and night, increased discharge during the day and especially in late afternoon and early evening, followed by a decline to low discharge again at night. Within a day, mean hourly discharge rates normally vary between a low of 700 m^3 and a high of 4950 $m^3 \cdot sec^{-1}$. Total discharge during weekends and holiday's are considerably reduced from weekdays. Similarly, average daily discharge during spring slightly exceeds mean summer discharge, yet is considerably less than mean daily discharge during winter. Based on the change in mean monthly discharge between pre- and post-regulation periods, the net reduction in summer discharge is approximately 8.8 billion m^3 of water, with an increase during winter, of 14.6 billion m^3 of water.

Regulation of daily and seasonal discharge flow rates and patterns affects the annual temporal and spatial distribution of other physical (e.g. temperature), chemical (e.g. nutrients, ions) and biological (e.g. plankton, invertebrates) factors.

Physical Description of the Nelson River Estuary

The physical aquatic environment and hydrodynamics of the Nelson River estuary are quite complex. This is due to the shallowness of the estuary, its fluted shape, high tides, variable discharge and the Coreolis Force. Extensive mud-flats which become exposed during an ebb tide, with the exception of a narrow (1 km), deep (5 to 8 m) central channel, dominate the nearshore region of the Nelson estuary. The estuary can generally be described as intermediate between a partially-mixed and an homogeneous estuary. Although primarily homogeneous (i.e. completely mixed from top to bottom), a narrow, stratified zone exists offshore during a high tide. This zone is ephemeral, becoming broken down and pushed offshore during the ebb tide.

Four physical zones have been described: 1) a freshwater zone composed entirely of freshwater, but that is affected by the tides, and extends between North Seal Creek and up to 10 km offshore of Port Nelson; 2) a nearshore estuarine zone beyond the riverine zone, characterized by low salinities (0 - 8 ppt), shallow depth and complete mixing; 3) a narrow stratified zone beyond the nearshore zone, which consists of moderate salinities (9 - 18 ppt) and weak stratification; and 4) a large offshore estuarine zone, characterized by moderately high salinities (>18 ppt), low temperatures, complete vertical mixing and depths usually in excess of 5 m. This zone extends from the stratified zone to the marine waters of Hudson Bay and varies considerably according to the tide.

The Nelson River estuary is subject to relatively high, semi-diurnal tides. Tidal amplitude, between spring and neap tides, ranges from 1.2 m to 4.5 m respectively. The height of the tide has a considerable effect on the size and integrity of each of the zones discussed above.

Variable river discharge rates exacerbate the influence of the tides. Low river discharge and a high flood tide push more saline water nearer shore and back up riverine water. High river discharge and a high ebb tide will pull freshwater further offshore, greatly protracting salinity and temperature profiles.

The combined effects of variable discharge, large semi-diurnal tides, shallow morphology of the estuary and the Coreolis Force, result in a complex environment where salinities, temperatures, flow rates, current and depth are continually changing. These conditions limit species composition and abundance of benthic and planktonic invertebrate and fish species.

Potential Impacts

Impacts, or effects of hydroelectric generating stations on the environment and ecology of the Nelson River estuary fall within two basic categories: impacts resulting from discharge regulation; and impacts related to directly or indirectly with construction and operation of a hydroelectric facility. These include fuel, chemical and oil spills; sewage handling; disturbance by increased usage, and "whale-watchers", that may result, because of improved access to Hudson Bay.

The greatest potential impacts on the estuary result from discharge regulation. The Limestone dam, approximately 100 km upstream of the estuary, currently regulates discharge; Conawapa, 27 km downstream of Limestone, will regulate discharge beginning in 1999.

Flow regulation by hydro facilities alters the temporal and spatial distribution of water, as well as temperature and chemical regimes, consequently affecting the downstream riverine and estuarine environments. As a result, changes in biological productivity, invertebrate and fish species composition and abundance, can be expected.

The following discussion identifies potential impacts to the river and estuary downstream of Conawapa. No assessment was made as to the magnitude or likelihood of occurrence of potential impacts. We attempted to be as impartial as possible in listing impacts, in order that the importance of each potential perturbation to beluga whale could be assessed by workshop participants.

1) Habitat alteration could occur due to altered seasonal discharge patterns and daily flow regulation. Estuarine and freshwater habitat will be reduced as a result of an increased marine:freshwater ratio during spring and summer. This effect has broad implications for determining the structure of estuarine food chains. The estuary may be altered on three planes: lateral (i.e. across the estuary), with a narrowing of the river and estuary; longitudinally (i.e. seaward), with a decrease in the distance and stability of the spring and summer freshwater plume; and vertically, with a decrease in depth of the river and the freshwater layer, during low discharge.

2) Increased freshwater habitat may be created under ice during winter. This may provide increased overwintering habitat for freshwater, semi-anadromous and anadromous fish, at the expense of habitat suitable for marine/cold water species. The under ice algal community could be affected by the change in composition of the bottom surface of the ice.

3) Decreased stability and increased temperature and salinity ranges within the riverine, nearshore estuarine, stratified and offshore estuarine zones may occur as a result of regulation, exacerbating the magnitude of tidal effects.

4) Increased flow velocities and scouring effects by the combination of high river discharge during an ebb tide of a spring tide.

5) Greater frequency and distance of salinity intrusion into the Nelson River. This can occur during normal operation and during intermittent dam shut-down periods, such as during coffer-dam removal inspection and soundings, spillway gate inspections etc.

6) The cumulative impact of upstream reservoirs could result in a significant delay in spring warming and fall cooling of the lower Nelson River and estuary. Storage of cold water during spring, and warm water during fall in reservoirs, may retard the annual temperature regime.

7) Retardation of warming and cooling of the Nelson River, may cause a steeper temperature gradient between tributary and mainstem water, possibly affecting fish species composition, distribution and abundance, timing of migrations and reproductive success.

8) Regulation ameliorates spring floods and evens out annual discharge patterns, resulting in significantly less water entering the estuary during spring and summer, than during winter. Therefore, a smaller proportion of nutrients than normal enters the estuary during spring, and a greater proportion during winter.

9) Changes in riverine and estuarine ecology, could affect productivity, including benthic invertebrate and fish abundance, distribution and species composition.

10) Increased turbidity and sedimentation due to erosion and sediment transport within new reservoirs, could cause a reduction in productivity, a loss of feeding opportunity and impaired feeding efficiency of invertebrates and fish.

11) Reduction or loss of anadromous fish stocks by elimination of access to spawning grounds or tributary streams by hydro dams.

12) The reduced size of the freshwater plume during summer will limit coastal movements and migrations of anadromous and semi-anadromous fish species.

13) Unknown effects of decreased estuarine stability on capelin, known to spawn in the vicinity of the estuary, and known to be an important food source for beluga whale.

Discussion Topics

The following section lists some possible discussion topics, with respect to beluga whale, as a result of the above direct and indirect impacts to the lower river and estuary.

1) Possible disruption in timing of arrival and departure of beluga whales from the estuary during their annual migration cycle, as a result of amelioration of spring run-off and retardation of annual temperature regime by upstream reservoirs.

2) Increased thermoregulatory and energetic costs due to decreased summer water volume and decreased spring and summer water temperatures, because of retardation of temperature increase by reservoirs.

3) Increased energetic costs associated with greater movements and increased stress due to crowding, because of low discharge and greater instability of the estuary.

4) Loss of feeding opportunity and efficiency due to loss of, or changes to, invertebrate and fish species composition, distribution and abundance.

5) Disruption of family and social groups.

6) Disruption of behavioral patterns and increased stress associated with increased frequency of movements.

7) The epidemiological environment may be enhanced because of increased stress due to crowding, on beluga.

8) Possible disruptive effects on beluga, of short-term shut-off of river flow during construction, such as during cofferdam removal, spillway gate inspections etc.

APPENDIX 2:
Beluga Workshop Agenda and List of Participants

Agenda
Manitoba Hydro and
Canada Department of Fisheries and Oceans Workshop

Monday, November 5, 1990.

18:00 - 22:00 Reception. Gander Room.

Tuesday, November 6, 1990.

09:00 - 09:20 Introduction and overview of the workshop sessions. Adjustments to Working Group Team Rosters as required.

09:20 - 09:40 Overview of the distribution, movements and abundance of the beluga of Western Hudson Bay. - Pierre Richard and Patt Weaver (DFO).

09:40 - 10:00 The Nelson River Estuary. A biological and environmental assessment. - Randle Baker (N/S Consultants).

10:00 - 10:20 Belugas in Arctic estuaries. - Tom Smith (DFO).

10:20 - 10:40 Break.

10:40 - 11:00 Possible relationships between estuaries and molting of the epidermis of beluga. - David St. Aubin (U. of Guelph).

11.00 - 11:20 Recent changes in the freshwater inputs to the Churchill River and Nelson River Estuaries. - Dennis Windsor (Manitoba Hydro).

11:15 - 12:00 Description of the assessment process.

12:00 - 13:00 Lunch.

13:00 - 15:00 1) Identification of the potential disturbances of the Conawapa Project on Nelson River hydrology and the on the estuary.

2) Identification of linkages to the beluga whale.

15:00 - 17:00 Initial impact assessment workshops.

Working Group 1
Concerning direct effects of changes in the freshwater inputs to the estuary on beluga.

Working Group 2
Concerning indirect (food web) effects on the beluga.

Working Group 3
Concerning socioeconomic impacts.

Wednesday, November 7, 1990.

09:00 - 09:30 Brief discussion re: previous day's progress.

09:30 - 10:30 Continuation of assessment exercises in each working group.

10:30 - 11:00 Break

11:00 - 12:00 Continue.

12:00 - 13:00 Lunch

13:00 - 15:30 Development of testable hypotheses to examine potential impact pathways identified in each working group.

Make recommendations to address research needs for monitoring and research.

15:30 - 17:00 Plenary session. Working group reports and discussion of the contents of the overall Workshop Report.

Working Group 1 - Direct Effects

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DFO, Winnipeg

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LGL, Toronto

Ray Schmidt (Facilitator)
IDS, Winnipeg

Don MacDonell (Rapporteur)
N/SC, Winnipeg

Tom Strong (Rapporteur)
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Tom Smith
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David St. Aubin
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Patt Weaver
DFO, Winnipeg

Max Dunbar
CSSA Cons., Montreal

Working Group 2 - Indirect Effects

Ray Hesslein
DFO, Winnipeg

Rob Stewart
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Greg McCullough
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Working Group 3 - Socio-Economic Related Effects

Noel Kaludjak
HTA, Rankin Inlet

Roy Bukowsky (Rapporteur)
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Daryl Headman
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Peggy Smith
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Barb MacKay (Facilitator)
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Emma Gorvie (Rapporteur)
Manitoba Hydro

Jack Orr
DFO, Winnipeg

Robert Moshenko
DFO, Winnipeg

Christine Michel
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APPENDIX 3: Working Group Rapporteur Reports

Notes concerning the Tables:

1. Tables 1 and 2 summarize discussions of the group as a whole.

2. Assessments of "Reliability and Applicability" of information and/or data presented in Tables 1, 2, 4, 5, and 6 are based on judgement of workshop participants.

Table 1. Potential effects of the proposed Conawapa project on Nelson River hydrology.

Activity	Disturbance	Reliability of Information
Station Operation	Change in temperature regime: The nature and magnitude of change cannot be characterized owing to limited records. Temperatures in the reservoir will be cooler than in the river some seasons, but warmer in others. Winter ice cover tends to insulate the reservoir, which may result in some warming. Water that remains open well into winter, will be colder than water under ice. There is some concern that a series of reservoirs will have an incremental effect on temperature regime in the estuary.	Good. Good.
	Change in sediment regime: Concentration of sediments are not expected to increase in the Lower Nelson because of reservoir development. No increases in sediment loads have been observed in the Lower Nelson as a result of earlier projects, except during initial (and short-term) reservoir flooding (Man. Hydro). Sediments will gradually accumulate in reservoirs, but not in downstream reaches. Fine-textured sediments are most likely to be transported to the coast. Deposition will be influenced by current and salinity regimes. DFO is establishing sediment budgets that will be used to determine the sediment regime of Nelson River (G. McCullough pers. comm.).	Good. Fair.
	Seasonal/daily change in water volume: Drought conditions have kept flows at historic levels despite the Churchill River diversion. Operation of generating stations results in a net reduction in discharge during summer (8.8 billion cu m) and a net increase in winter (4.5 billion cu m). Changes associated with Conawapa will be incremental in terms of their effect on the estuary; the greatest change in the Nelson River flow regime came after Kettle Station was installed. Care must be taken not to over-interpret the significance of short-term changes (over the past 10-15 years), which may not reflect the full range of variation possible under the controlled regime. In normal and wet years, the effects of peak flows will be felt in downstream areas. Flows and volumes determine water levels and are major factors influencing temperature, and biological productivity.	Good. Good. Fair.

(Cont'd.)

Table 1 (cont.). Potential effects of the proposed Conawapa project on Nelson River hydrology.

Activity	Disturbance	Reliability of Information
Station Operation (continued)	Change in water chemistry (emphasis mercury): Increase in mercury concentration in the aquatic environment as a result of creation of Conawapa forebay, is expected to be small. Difference in mercury levels in fish collected from above and below Long Spruce G.S. has not been detected (Baker 1991).	Good.
	Physical barrier: Long-term effects are anticipated as a result of installation of a generating station.	Good. (Implicit)
	Potential for increased downstream access: Conawapa may make it easier to reach the estuary by boat because reaches that are currently difficult to navigate can be bypassed, or more easily negotiated once the reservoir is in place. This raises concerns about the integrity of historic and natural resources in and near the estuary. Note, however, that navigation will remain hazardous and large increases in boat traffic are not expected.	Good.
	Increase in downstream sewage effluent: No significant problems are anticipated. At Limestone, Manitoba Hydro is required to not treat sewage.	Good.
Construction	Increase in downstream sewage effluent: No significant problems are anticipated. Sewage facilities required for 1500 construction workers may not be chlorinated.	Good.
	Improved access to estuary: More people associated with construction of Conawapa can afford to charter aircraft or rent boats to visit the estuary.	Fair.

Table 2. Interactions and linkages between Conawapa Project disturbances and the beluga whales of the Nelson River estuary.

Disturbance	Link to Beluga	Notes/Rationale	Reliability/ Applicability of Information
Temperature change	Molting of epidermis.	Refer to St. Aubin's introductory paper. Beluga may rely on warm water to stimulate molting.	Fair.
	Access to the estuary.	Change in temperature regime may affect timing of migration to and from estuary.	Fair.
	Metabolic stress.	Thermal advantage provided by warm, estuarine water may be altered.	Good.
	Food production.	Change in estuary temperature regime may alter the relative importance of estuarine production pathways and processes (Parsons et al. 1988 and 1989).	Good.
Change in Sedimentation	Loss of capelin spawning sites.	Increase in sedimentation in the estuary may negatively affect capelin spawning habitat along the estuary coast.	Rel. good. App. fair.
Change in Flow Regime	Molting of epidermis.	Refer to St. Aubin's introductory paper. Fresh water is likely to aid in the molt process.	Good.
	Stranding in shallows.	Low tide coinciding with low river discharge may result in stranding of belugas in the lower Nelson River as has been observed in the Churchill estuary (R. Bukowsky pers. comm.)	Good.
Increase in Mercury	Contaminated food source.	Increase in mercury in food web could cause increase in mercury in beluga tissue.	Good.
Physical Barrier	Loss of anadromous fish habitat.	Decrease in anadromous populations of fish could affect beluga food supply.	Fair.
	Change in estuarine food supply.	Change in Nelson River hydrology could change estuarine food webs through alteration of freshwater food sources. This could affect the role of the estuary as feeding habitat for beluga.	Good.
Increased Access to Estuary	Harassment.	Harrassment of belugas in the estuary will disturb beluga.	Good. (Implicit)
	Hunting.	Increased hunting activity will result in increased harassment and reduction in population numbers.	Good. (Implicit)
	Entanglement in gillnets	Increased fishing in the estuary will increase chance of entanglement in gillnets with subsequent risk of death to belugas. Entanglement and death of whales has been reported in Churchill (R. Bukowsky pers. comm.).	Good.

Table 3. Summary of discussions of the Direct Effects Working Group concerning interactions between changes in Nelson River hydrology and beluga whales.

Theme	Issues, Concerns and Interactions
General Comments re:	
Relationship between Changes in Temperature, Flow and Salinity	Temperature, flow regime, and salinity are inter-related and are difficult to consider separately. There is no information on threshold responses of belugas to changes in salinity. There is a basic lack of information on basic beluga ecology. Any statements made about site- or parameter-specific effects (i.e., regarding a particular estuary or flow/temperature value) must be considered speculative.
Knowledge Gaps and Research Needs	Changes in flow regime due to Conawapa will likely be small, but there is not enough data on beluga-flow relationships to adequately assess impacts. Laboratory tests are required to determine threshold responses of belugas to changes in their environment; however, determining such thresholds in complicated by stresses induced through capture and handling of animals, which make it difficult to apply results to "natural" conditions. The wide range of sodium values observed in whales raises questions about specific processes that may be affected by the overall regulation and development scheme for Nelson River. We must look at changes in other estuaries to evaluate changes in the Nelson estuary. For example, we know that belugas move between the Nelson and Churchill estuaries. We must also look at the effects of all hydroelectric development in the Hudson Bay region. Any review of the data base compiled on belugas over the past 20 years must take into account the effects of commercial hunting (e.g., recovery of populations may reflect reduction in commercial hunting). Change has already occurred in the Nelson River due to hydroelectric development (but their effects are not known); further change may affect lower trophic levels. Data indicate belugas showed some response to reduced flows in the Churchill River after diversion (but the nature of response not specified). There is a great deal of variability and experimental error in monitoring beluga behavior and estuarine conditions. The cumulative effects of hydroelectric development must be evaluated. Some way must be found to analyze cumulative effects to allocate and promote research and prevent piecemeal approaches to development as it relates to environmental protection. Impacts addressed at the "micro" level have little value, since such impacts by themselves are likely to be negligible. Such an approach does not promote understanding of problems or encourage research needed to deal with them. Again, it is impossible to say how belugas will respond to "micro-changes" given their ability to adapt to change. The condition of animals is a better indicator of stress and progressive impact than animal numbers and their distribution. (cont.)

Table 3. (cont.) Summary of discussions of the Direct Effects Working Group concerning interactions between changes in Nelson River hydrology and beluga whales.

Theme	Issues, Concerns and Interactions
Knowledge Gaps and Research Needs (continued)	Confidence limits associated with pre-and-post development (disturbance) changes in environmental conditions are too large to make firm conclusions or identify cause-and-effect correlations.
Change in Temperature and:	
Moulting	Although there is no firm evidence that development will alter the temperature regime downstream of the project, it was proposed that the project may compress the volume of warm water in estuary. It's impossible to specify temperature-related effects in the absence of reliable data on beluga behavior. Not enough is known about temperature changes as they might affect moulting. Incremental changes in temperature regime throughout the Nelson River system have to be addressed. Even though temperature regime may change over time, belugas are adaptable and may adjust to such change.
Beluga Whale Access to the Estuary	Whales reach the estuary in May before ice-breakup (there is always an open channel in the river by the first week of June) and remain in ice-pack, where they do not appear to seek openings leading to open sea. Belugas may enter an estuary at the first possible opportunity in spring. Hydroelectric development may promote abnormally early breakup and reduce the volume of river ice cover by half. (At minimum, a 2-year study is required to document breakup under the altered regime.) If cool conditions come late in fall, belugas may remain longer than is good for them (but this is not likely to be a critical factor). Whales in Mackenzie Delta leave in August, before the river cools significantly. Belugas are not likely to be trapped in estuaries, since they routinely move from sea to estuary several times a day. It is not known whether whales have distinct preferences as to which estuary they will enter and use? In 1990, belugas remained later than usual in Churchill River estuary. It is not known what this later than normal departure was in response to. To feed? Because of ice conditions? To take advantage of warm water as long as possible? (cont.)

Table 3. (cont.) Summary of discussions of the Direct Effects Working Group concerning interactions between changes in Nelson River hydrology and beluga whales.

Theme	Issues, Concerns and Interactions
Beluga Whale Access to the Estuary (continued)	Changes in temperature regime due to Conawapa will likely be small, but there is not enough data on beluga-temperature relationships to adequately assess impacts. Use of estuaries by whales is dynamic and variable and involves the life cycle of the population as a whole. Whales adapt to changes in their environment, so minor changes in temperature in themselves may not be significant. We need to know more about the animal-its behaviour and movements- through telemetry studies before we can assess the effects of estuary temperature regime on whale populations.
Increased Human Access to Estuary and: Harrassment	More people will have access to the estuary with Conawapa in place. More people are likely to show an interest in belugas and the estuary. While access can be controlled to some extent, the proponent cannot govern what people do and where they go after work hours. Manitoba Hydro can provide employees with environmental brochures when the check into camp and can make pilots aware of environmental regulations; but Hydro's authority cannot extend beyond that. Whale-watching may become more popular and have an impact on belugas in the future. Whale-watching activity can be managed to protect belugas-e.g., by limiting boat activity and telling people not to disturb or closely approach animals. Groups opposed to capturing whales are encouraging whale-watching in the north. Whale-watching in the St. Lawrence estuary is a thriving industry with rules, guidelines, and enforcement measures in place. Belugas there have become habituated to human presence and disturbance and noise. Regulations regarding people and whales in the St. Lawrence estuary are insufficient; studies of whale behavior are required to fully assess impacts. Organized scuba-diving activity in estuaries where belugas are present has the potential to create significant adverse impact, although it is difficult to prove harassment. The issue of whale-diver interaction has been reviewed in the Churchill estuary; however, murky waters may discourage scuba diving in the Nelson estuary. DFO provides no mechanism to restrict human access to estuaries inhabited by belugas and the role and jurisdiction of the Natural Resource Officer regarding access to belugas in estuaries is unclear. British Columbia has regulations to protect whales in Robson Bay. Similar environmental regulations should be established for all estuaries. (cont.)

Table 3. (cont.) Summary of discussions of the Direct Effects Working Group concerning interactions between changes in Nelson River hydrology and beluga whales.

Theme	Issues, Concerns and Interactions
Hunting	Native employees exercising treaty rights could have an effect on belugas and the estuary. The Manitoba umbrella organization of Indian Bands has informed the Public Utilities Board that natural resources on unoccupied crown lands belong to native peoples.
Entanglement in Gillnets	The entanglement of belugas in gillnets is a potential impact in the Nelson River estuary; such problems have been documented elsewhere in Canada.
Change in Flow Regime and:	
Stranding in Shallows	Stranding of whales in shallow water is common but not frequent. Stranding occurs most often following extremely high tides (this happens 1 to 5 times per month at Cunningham Inlet; in each case, whales were able to escape on the next tide). Stranded whales are vulnerable to predation. Whether stranding occurs may depend on specific habitat conditions. Conditions favorable for stranding may be more pronounced in Nelson estuary; however, no case of stranding has been documented in western Hudson Bay. While whales are not likely to die because of stranding, internal organs may be damaged, as has been recorded in pilot whales. We don't know the long-term impacts on belugas that have been stranded and escaped. Telemetry studies at Cunningham Inlet indicated that "did well" after being stranded. Operation of Conawapa may result in 0.5-1 m fluctuations in water level in the estuary and this could influence stranding. Overall, stranding is not expected to be a major source of impact. The main concern is human presence and handling of whales when they are stranded. Also, it may be possible to coordinate flow pattern (at Conawapa) during and after extreme high tides to minimize opportunities for stranding.
Change in Temperature and Flow Regime and:	
Change in feeding patterns	Analysis of lipid levels in plasma samples from belugas in Churchill estuary indicate whales had been feeding 4 to 6 hours before they were captured. No feeding by belugas has been observed in the Churchill River estuary.

Table 4. Pathway of indirect (food chain) effects of project disturbances on Beluga of the Nelson river estuary.

Beluga Food Item	Rationale for Selection of Food Item	Reliability and Applicability of Information
Capelin (represents marine- coastal species)	Beluga have been observed feeding on capelin in estuaries (Watts and Draper 1986) and have been observed in the stomachs of beluga harvested at Arviat (R. Stewart pers. comm.) Skates, sculpins and cod have also been reported in beluga stomachs (Breton-Provencher 1979). Capelin were chosen as the VEC in an effort to adopt a worst case approach with regard to potential effects. The assumed greater dependency of capelin on spawning habitat in the coastal environment of the Nelson river estuary led to this decision.	Good. Fair.
Lake Whitefish (represents anadromous estuarine species)	Lake whitefish have been reported in the stomach of beluga inhabiting the estuaries of western Hudson Bay (Comeau 1914 in Baker 1989). Lake whitefish were also reported in beluga stomachs from eastern Hudson Bay (Breton-Provencher 1979). Other freshwater and anadromous species have also been reported in beluga stomachs (lake cisco [Morin and Dodson 1981], lake trout [Breton-Provencher 1979] and longnose sucker [Comeau 1914]) however it was decided that lake whitefish could act as a proxy in regard to concerns for these other species.	Good. Fair.
Invertebrates	Beluga of the eastern Hudson Bay eat polychaetes, mysids, gastropods, decapods and bivalves (Breton-Provencher 1979). Western Hudson Bay beluga have been reported to feed on polychaetes and a variety of other invertebrates. No record of bivalves in beluga stomachs has been made (R. Stewart pers. comm.) Invertebrates, as a group, were chosen as a food item of importance to beluga.	Good. Good.

Table 5. Potential effects of project disturbances (from Table 2) on food resources (from Table 4) of beluga that occur in the Nelson River estuary.

Theme	Issues, Concerns and Interactions	Reliability and Applicability of Information
General comments re: importance of the Nelson River to coastal energetics.	Based upon the lack of any observed increase in weight, after belugas have spent time in estuaries, estuarine food sources are unlikely to provide more than a maintenance food supply. It seems unlikely that the Nelson River estuary contributes greater than 10% of the beluga's annual energy needs. The seasonal change in Nelson River flow regime presently experienced as a result of hydroelectric could mean that some portion of the fixed carbon and nutrient supply which would otherwise arrive in summer,now arrives in winter and is effectively lost to estuarine production.	Good. Fair. Poor.
	Estuaries may be important nursery habitat for lake whitefish. In the Mackenzie River estuary, a large portion of the anadromous lake whitefish population utilize the inner estuary extensively for the first few years after emerging from upstream spawning locations.	Good.
	Effects on invertebrates may be felt directly by beluga which feed on them, and also indirectly through fish which feed on invertebrates and are subsequently preyed upon by beluga.	Good.
	The extent to which fixed carbon and other nutrients transported to the estuary are utilized by the invertebrate community is unknown. Based on other estuaries this source could be a significant contribution to the estuarine energetic picture.	Fair.
Temperature change and:	Assuming a three hour storage capacity of the proposed Conawapa forebay, the possibility of the project affecting Nelson River water temperature is slight.	Good.
	Diurnal fluctuations in flow to estuary may lead to reduced temperature stability at the estuary (i.e. there will be greater fluctuations in temperature). However if mixing rate in the estuary is such thatit dampens the diurnal temperature effects of river discharge, then loss of temperature stability in the estuary would not be a concern.	Good.
Lake whitefish	May be affected by alteration in estuarine temperature regime.	Fair.
Capelin	Unlikely to be affected by Conawapa temperature related effects because of the location of their habitat in relation to the zone of temperature influence of Conawapa.	Good.

Table 5. (cont.) Potential effects of project disturbances (from Table 2) on food resources (from Table 4) of beluga that occur in the Nelson River estuary.

Theme	Issues, Concerns and Interactions	Reliability and Applicability of Information
Invertebrates	Would likely be affected by alteration of the temperature regime of the estuary.	Good.
Sedimentation and:	Construction activities, and bank scour and shoreline erosion (especially in early years of operation) will increase coarse sediment in the reservoir upstream of Conawapa. Some increase in fine sediment may result; monitoring of Limestone should provide a good indication of the sediment inputs that will result from Conawapa. There appears to be no problem currently, and it is not likely that Conawapa will alter the downstream sedimentation regime.	
Lake whitefish	No direct impacts are predicted. Indirect effects through lake whitefish feeding on invertebrate community may result.	
Capelin	No effect on capelin is expected. Any increase in fine suspended sediments would not affect spawning habitat. Fines would be deposited further offshore.	
Invertebrates	Filter feeding invertebrates within depositional zones could be negatively affected by an increase in fine particulate deposition.	
Chemical change and:	Flow regime, seasonality and storage time dictate that Conawapa will not affect current nutrient sopply to the estuary. Concentrations of mercury are not expected to be affected by Conawapa. Beluga of Hudson Bay have higher concentrations of mercury in their tissues than do beluga from the High Arctic. This could be due to the high number of dammed rivers within the Hudson Bay watershed (R. Stewart, planned paper).	
Lake whitefish	No effect.	
Capelin	No effect.	
Invertebrates	No effect,	
Physical barrier and:		
Lake whitefish	The physical barrier created by construction of the generating station will block passage of anadromous lake whitefish to upstream Nelson River mainstem and tributary habitat.	

Table 5. (cont.) Potential effects of project disturbances (from Table 2) on food resources (from Table 4) of beluga that occur in the Nelson River estuary.

Theme	Issues, Concerns and Interactions	Reliability and Applicability of Information
Capelin	No effect.	
Invertebrates	No effect.	
Flow alteration and:	The Conawapa project will not affect seasonal flow regime. Amplitude of daily fluctuations in flow regime will downstream of Conawapa generatin station will result in decreased benthic productivity in riverine habitat (Refer to R. Baker discussion paper for refs.) Salinity intrusion into the estuary could increase substantially, especially if minimum river flow coincides with incoming tide. Regions normally exposed to moderate salinities could experience short term exposures to higher salinities. The size of the mixed estuarine zone could be increased. Periodicity of river flow events could have an effect on organisms which rely on normal tidal cycles. The reservoir of fresh water at the inner estuary will serve as a buffer and will mediate changes in the salinity regime of the estuary. If the estuary resrvoir of fresh water is equivalent in size to the Conawapa reservoir, then it will be sufficient to dampen frontal changes.	
Lake whitefish	Could affect area/volume and location of estuarine habitat suitable for anadromous lake whitefish.	
Capelin	No effect.	
Invertebrates	Could affect invertebrate habitat suitability. Only those species with tolerance for salinity change may adapt to increased zone of mixed salinity. Most species in estuaries are by nature, euryhaline and so the invertebrate community would have the capacity to adapt.	

Table 6. Spatial and temporal overlap of Conawapa project disturbances with food resources (Valued Food Components - VFCs) of beluga of the Nelson River estuary.

Project Disturbance versus Beluga Food Resource (VFC)	Spatial and Temporal Overlap	Reliability and Applicability of Information
Temperature change and: Lake whitefish	Spatial overlap = 1 - 10% The location of spawning habitat, in relation to the area that may be subject to temperature change resulting from Conawapa, is unknown and requires some research effort. The temperature fluctuation that spawning habitats are naturally exposed to is likely as great or greater than changes induced by the project. However, concerns relate to the overall trend in temperature change that could, in the long term, affect spawning success.	Poor.
	Temporal overlap = 100%	Good.
Invertebrates	Spatial overlap = less than 1% It was estimated that the estuarine habitat that could be affected by change in temperature resulting from formation of the conawapa forebay would be minor.	Fair.
	Temporal overlap = 1 - 10% Effects would result from short term pulses of temperature change.	Fair.
Sedimentation and: Lake whitefish	Spatial overlap = less than 1% Effects on lake whitefish would be indirect, through shifts in the benthic community, and were estimated to be small based on the estimate of effects on invertebrates.	Good.
	Temporal overlap = 10 - 100% Depending on the frequency of feeding in the affected area.	Fair.
Invertebrates	Spatial overlap = 1% Loss of a portion of the ice scour zone (in the forebay) due to the project is important for supplying organic material to the estuary. As the decrease is spread over a large area and effects would be very small in any particular area.	Poor.

Table 6. (cont.) Spatial and temporal overlap of Conawapa project disturbances with food resources (Valued Food Components - VFCs) of beluga of the Nelson River estuary.

Project Disturbance versus Beluga Food Resource (VFC)	Spatial and Temporal Overlap	Reliability and Applicability of Information
	Temporal overlap = 100% Effects will extend over the year.	Good.
Physical barrier and: Lake whitefish	Spatial overlap = 100% The anadromous lake whitefish may have only one spawning location in the region. If this location is upstream of Conawapa then a 100% loss of habitat would result. If downstream then no spawning habitat would be lost.	Fair.
	Temporal overlap = 100% The effects would be felt throughout the life of the project.	Good.
Other species	Spatial overlap = greater than 10% Lake whitefish may not be representative of the spawning habits of other species such as lake cisco and brook trout, which use tributaries for spawning. The effects will be proportional to the per centage of lost spawning habitat.	Fair.
	Temporal overlap = 100% The effects would be felt throughout the life of the project.	Good.
Flow alteration and: Lake whitefish	Spatial overlap = 1 - 10% Effects of flow alteration due to Conawapa would be in the 1 - 10% range (as per invertebrates) or less, given that lake whitefish are motile and would likely move to most suitable estuarine environment.	Fair.
	Temporal overlap = 100% Effects would occur year round.	Good.

Table 6. (cont.) Spatial and temporal overlap of Conawapa project disturbances with food resources (Valued Food Components - VFCs) of beluga of the Nelson River estuary.

Project Disturbance versus Beluga Food Resource (VFC)	Spatial and Temporal Overlap	Reliability and Applicability of Information
Invertebrates	Spatial overlap = 1 - 10% The size and shape of the estuary will dampen the effects of River flow alteration on it. As no more than 10 to 15% of the estuary volume is freshwater, effects due to changes in fresh water flow would be quantitatively some portion of that.	Fair.
	Temporal overlap = 100% Effects would occur year round.	Good.
Overall "food chain mediated" impacts on beluga of the Nelson River estuary	Based on discussions of individual effects, it was assumed that overall effects on food resources (VFCs) of the beluga (i.e. as determined for lake whitefish, capelin and invertebrates), were not likely to reduce existing populations by more than 10%. Similar magnitude of effects on belugas would occur only if they were 100% reliant on estuarine food sources. There is no information to support 100% reliance on estuarine food sources. It was assumed that a likely upper limit of food-related impacts could affect the population of beluga at a 5% level. Uncertainty, with respect to the level of population effects was considered to be high. This uncertainty level may be the driving force behind research regarding food-chain related impacts.	Fair.

Table 7. Summary of discussions of the Socioeconomic Effects Working Group concerning interactions between change in human activity patterns and beluga.

Theme	Effects, Concerns and Interactions
Tourism and the Potential for Disturbance and Harrassment of Beluga	Improved access to the estuary and an increased population base during the construction of the generating station could result in an increase in the harassment of beluga whales. Experience in Cunningham Inlet supports the concern over the "skittish" nature of belugas (B. Sjare, pers. comm.). Small engine noise disrupts their activity. During construction there will likely be an increase in the number of flights to the estuary to view whales. However aircraft may be inclined to fly at increased altitudes to enable more whales to be seen. More boat traffic downstream of the project site may result from increased river use by construction workers, residents of Gillam and private tour operators. However it was proposed that the Conawapa Project would not significantly increase tourism either in the form of whale watching or sport fishing. The tourism industry in Churchill is too well established (R. Bukowsky pers comm.). There may be some opportunity to use the trestle at Port Nelson for whale watching. However there is concern about how long it would take belugas to habituate to this activity. Belugas movements into and out of the estuary may be interrupted frequently and there is a need for more information on what the effect may be of this increase in movement. Scuba diving among the whales was suggested as a tourism related disturbance, however the turbid waters of the Nelson R. estuary would probably reduce the attractiveness of this activity. Observations at Cunningham Inlet show that whales returned to the estuary within 24 hrs. after being disturbed by boat noise and in 48 hrs when disturbed by hunting activity. Similar experience has been reported from the Nastapoka estuary. When disturbed by small engine noise, belugas escape to small coves and return sometime later. It was reported that Louise Caron, in her studies, observed no change in beluga activity when helicopters flew at altitudes in excess of 500 ft. Flying at altitudes less than 300 ft. caused belugas to dive. There is a concern, based on observations made by Coron and Smith (1990) that long term, hunting related disturbance, may cause earlier calving. With regards to how noise affects beluga behaviour, not all react in the same manner or to the same degree. Females and calves will generally return earlier to a location after being disturbed (Caron and Smith. 1990). Despite hunting activity at Nastapoka, belugas which were identified on the basis of scar patterns, and were observed over a period of 2-3 years, returned annually to the estuary (attributed to observations by L. Caron). The concern regarding harassment was highlighted by the postulation that the Nelson River estuary may represent a "safe place" for the whole Western Hudson Bay population and that if there is not more than one "safe place" then the entire population may be affected. It was suggested (J. Orr pers. comm.) that the entire coastal area may serve as a "safe place". (cont.)

Table 7. (cont.) Summary of discussions of the Socioeconomic Effects Working Group concerning interactions between change in human activity patterns and beluga.

Theme	Effects, Concerns and Interactions
General Comments Related to Reactions of Beluga to Human Disturbance	Experience from other estuaries indicates that belugas have a high threshold for disturbance. Examples sited were Mackenzie Delta, Clearwater Fiord, Nastapoka, and Ungava Bay. Regardless of disturbance the whales returned to the same place every year. As a result of the decrease in freshwater input to the Churchill R. estuary, belugas are now observed moving farther upstream to access freshwater (as far as the pumphouse). This has resulted in an increased opportunity for tourists and residents to view the whales. Casual observations of whales using the Churchill River estuary, both before and since the Churchill River diversion would suggest that the diversion has had little effect on whale use (R. Moshenko, and B. Sjare pers. comm.). Experience in Arviat (as told to N. Kaludjak by hunters) suggests there have been no apparent substantial population changes over time (at least one generation). A concern was expressed over an increase in recent years, in the use of faster, noisier airboats on the Churchill River and the disturbing effect this may have on the whales.
Hunting (Background)	Hunting activities are presently carried out by native northerners. The regulation of hunting varies depending on the aboriginal status of the hunter and the location. In exceptional cases non-native hunters can hunt beluga but generally a case must be made in respect to need (i.e. food for human consumption). Various factors may be influencing a change in the traditional hunting patterns. Development in the north is seen as one factor contributing to this change. This is probably a result of a combination of a change in the local distribution of traditionally hunted wildlife and a change in distribution of the hunting population. Rankin Inlet residents continue to hunt beluga, and the art of whale hunting is being passed on to the young (N. Kaludjak pers. comm.). There is presently some inter-settlement trade in maktak (choice portions of whale meat - although all of whales are generally consumed by people and dogs) and other country foods that are in excess of community needs. No export of whale food products beyond the NWT is presently allowed. Some hunting of beluga in Churchill is conducted by individuals from Arviat and Rankin Inlet while visiting the community of Churchill.
Potential Effects of the Conawapa Project on Hunting	Employment at Conawapa during the construction of the generating station, of Inuit from Rankin Inlet or other NWT communities who traditionally hunt beluga, could lead to an increase in hunting in the Nelson River estuary during weekends and other time off. (cont.)

Table 7. (cont.) Summary of discussions of the Socioeconomic Effects Working Group concerning interactions between change in human activity patterns and beluga.

Theme	Effects, Concerns and Interactions
Domestic Fishing and:	
Entanglement of Belugas	Presently there is minimal fishing effort in coastal waters near the Nelson River. There is some chance that improved access to the coast may result in more domestic gillnetting activity. This could lead to an increase in the number of beluga that become entangled in the fishing gear. In Churchill approximately one beluga per year becomes entangled in gillnets. While it was agreed that these are legitimate concerns, it does not appear likely that an increase in domestic fishing at the coast would occur as a result of improved access to the coast. The coastal fishing would require too much effort compared with the relative ease of fishing upstream closer to the present fishing locations.
Loss of Prey for Beluga	A good deal of the current fishing effort is focused on whitefish, ciscoes, suckers, Arctic charr and anadromous brook trout. It was postulated that if fishing effort increased upstream, it could be at the expense of available food of the beluga. Beluga have been reported to feed on capelin in the Churchill estuary and on other fish species in other coastal areas, however there is presently not evidence of beluga feeding in the Nelson River estuary.
Mitigation of Effects Through:	
Education	Education efforts by Manitoba Hydro to ensure all workers are well informed of the potential for disturbance of beluga which use the estuary. Efforts among Manitoba Hydro, Natural Resources and DFO are needed to educate both the public at large, and Manitoba Hydro and contractor employees regarding ways to minimize disturbance effects.
Regulations and Guidelines	Stricter enforcement of present regulations and development of new ones to reduce the incidence of harassment. Presently jurisdiction responsibilities appear unclear. Review of present fishery regulations to address the potential for increased hunting/fishing pressure. Existing guidelines (e.g. Tourism, DFO Whale Watching Guidelines and the Alberta model for guiding) should be reviewed and studied with a view to developing workable, effective guidelines applicable to the situation in N. Manitoba. (cont.)

Table 7. (cont.) Summary of discussions of the Socioeconomic Effects Working Group concerning interactions between change in human activity patterns and beluga.

Theme	Effects, Concerns and Interactions
Regulations and Guidelines (cont.)	As part of licencing of the construction of Conawapa, enforceable terms and conditions regarding adherence to Whale Watching Guidelines developed by DFO could considered. Note: guidelines are not otherwise legally enforceable as they are beyond jurisdiction of the Fisheries Act. Institute a licencing policy for commercial tour operators to improve awareness and compliance with codes of conduct.
Co-Management and Cooperation	Access to and use of, the Nelson River area may receive varying degrees of protection depending on its future status, either as part of the Cape Churchill Wildlife Management Area or if it became a National Park. Co-management agreements similar to those in place or being developed (e.g. Western Arctic, Northern Quebec and Southeast Baffin) could result in improved capability to better manage these beluga in the face of changing northern lifestyles and need. Any existing plans or plans under consideration for a National Park, Wildlife Management Area or likewise should be investigated with regards to what opportunities may soon exist to improve control over human activities in the area of concern. Review plans with Parks Dept., Dept. of Tourism and Highways etc. regarding development of road to York Factory, Port Nelson and Churchill so that research and monitoring studies can be developed.

Table 8. Summary of Working Group 1 discussions related to data requirements and research needed to assess impacts of hydroelectric development on estuaries and associated direct effects on beluga populations.

Subject	Data Requirements and Research Initiatives
Hydrologic Modeling	Manitoba Hydro is preparing a dynamic hydrologic model of Nelson River that will provide baseline data on the water regime as it relates to the estuary. This information will be available in early 1991 and can be used to (a) determine flood/drawdown conditions for any flow regime, and (b) calculate heat budgets. The model will not specify the operating regime for individual dams. Hydrologic data will be made available to researchers on a cooperative basis. Manitoba Hydro can install sampling/recording platforms to collect data on hydraulic and water quality (i.e., temperature, salinity, etc.).
Satellite Imagery	NOAA satellite imagery provides timely information (6 to 9 images per day) on relative surface temperature, turbidity, and ice cover that can be used as part of an ongoing environmental monitoring program to assess relationships between hydrologic regime and beluga movements and activities. It may be possible to obtain satellite data at no cost through a cooperative research agreement. If NOAA data are used, they must be retrieved on a daily basis and coordinated with a ground-truthing and whale telemetry programs.
Beluga Telemetry	It is essential that belugas be equipped with monitoring devices (telemetry) to effectively assess how changes in water regime might affect whales. Sensor systems attached to belugas would establish behavioral patterns, temperatures, and water depths at specific sites visited by whales. Transmitters would have to be placed on makes, females, and juveniles to provide data on sex- and age-specific behaviour. Data generated from whale telemetry studies can then be correlated with the satellite data retrieved for known dates and times of day. DFO has identified the need to sample belugas more extensively throughout their range and to conduct research in areas where whales congregate (in Hudson Strait, for example). One objective of these studies is to identify discrete beluga stocks through DNA marking. To do this, DNA samples must be collected from as many areas as possible, including the Nelson estuary. Such research initiatives would help determine which stocks use which estuaries, and whether there is exchange between estuaries. The fact that belugas are not repopulating estuaries where they had been extirpated suggests that stocks from eastern and western Hudson Bay are discrete. The scope of research needed to answer fundamental questions about beluga ecology may be too broad to be addressed in one, all-encompassing program. Instead, it may be advisable to break the program into segments as part of a five-year plan whose goal would be to assess beluga stocks and their distribution in light of impact-related concerns. (cont.)

Table 8. (cont.) Summary of Working Group 2 discussions related to data requirements and research needed to assess impacts of hydroelectric development on estuaries and associated direct effects on beluga populations.

Subject	Data Requirements and Research Initiatives
Sight-surveys	Monitoring programs based on aerial surveys are of limited value because confidence limits are too large to draw reliable conclusions on animal movements and behaviour. Observation of belugas in the Nelson estuary from shore-based platforms provides information of limited value unless individually marked animals (with telemetry devices or visible markings) are used. Unfortunately, marking whales with visible dyes or tags is impractical for long-term studies because such markers are sloughed off during the molt; however, it may be possible to mark whales with a flexible "flipper-band" that would stay in place for longer periods. Mark-recapture methods are inadvisable because they are disruptive and may be statistically suspect, due to high confidence limits attached to the resulting data.
Physiological Studies	Physiological research should be conducted to monitor changes in energy metabolism, fat storage, and general condition of belugas. This involves capturing the same animal several times through the season.

SUMMARY (Working Group 2 Research Requirements)

First Priority:
1. whale telemetry studies (and associated physiological investigations of captured/marked animals);
2. DNA marking program to identify whale stocks.

Second Priority: satellite-based monitoring of the physical character-istics of Nelson estuary that can be correlated with telemetry studies.

Third Priority: monitor Nelson estuary habitat (temperature,salinity, turbidity and sedimentation, plankton, water levels and flows, etc.) through repeated sampling from fixed platforms.

In addition to providing information on animal movements and behaviour, telemetry studies would show where belugas are feeding (in terms of depth as well as geographic locale). Known feeding areas can then be sampled to identify forage species. The principal value of beluga telemetry is that it uses the animal as a sampling platform and so delivers highly reliable and spatially accurate information on key biological/physical factors needed to assess impacts.

At the same time, we need to know what is happening to beluga habitats, since destruction or degradation of habitat influences the welfare of animal populations.

Table 9. Summary of Working Group 2 discussions related to data requirements and research needed to assess impacts of hydroelectric development on estuaries, and associated indirect (food-chain mediated) effects on the beluga population that utilizes the Nelson River estuary.

Subject	Data Requirements and Research Initiatives
Feeding in Estuaries.	Beluga were presumed not to feed extensively in estuaries. However evidence is lacking as to the extent to which beluga are dependant on estuarine food sources. The dependency of estuarine energetics on terrestrially derived fixed carbon and nutrients is unknown. Stable isotope studies of tissue of Nelson River estuary belugas as well as of some selected fish and invertebrate species were recommended to help derive a model of estuarine energy pathways and to specifically help determine the extent to which beluga are dependant on estuarine food sources.
Nelson River Estuary Modelling	The capability to predict effects of hydroelectric development on the estuary is constrained by the lack of understanding of Nelson river estuary hydrodynamics. A research effort is recommended to develop and refine a physical/chemical model of the estuary that is responsive flow change and would be useful in describing estuary effects.
Beluga Tagging Studies	The extent and frequency of use of estuaries by beluga has been investigated and described in other estuaries. Tagging studies that would permit the tracking of onshore-offshore movements of beluga within the Nelson River estuary are necessary to help assess the importance of the estuary to them. Tracking of beluga movements along the coast with a view to assessing time spent in estuarine versus offshore habitat would contribute to an overall better assessment of habitat use and importance.
Cumulative Effects Modelling in Hudson Bay	Studies designed to describe nutrient cycling and availability in Hudson Bay are prerequisite to understanding the effects of manipulating the fresh water flow on the Hudson Bay environment. Where are fixed carbon and nutrients going? Where and when are they being utilized?
Spawning Habitat of Anadromous Fish Populations	The locations of spawning habitat of those anadromous fish species which may be prey of beluga that use the Nelson River estuary need to be identified. The importance of the loss of access to upstream locations, to the survival and/or size of these fish populations, can not be assessed without this information.

Table 10. Summary of Working Group 3 discussions related to data requirements and research needed to assess impacts of hydroelecric development at the Conawapa site related to human use aspects of the estuary and their effects on beluga whale.

Subject	Research Initiatives and Data Requirements
General Information Needs and Approach to Research and Monitoring	Results of research into biological and other environmental factors (such as fish migrations, changes in hydraulic regime etc.) which may influence beluga distribution, movement and activity in the estuary will be essential to an understanding of what effect changing human-use patterns (related to fishing, hunting, tourism) may be having. A holistic approach to research on beluga whales of the Nelson River estuary was recommended. It was considered that the estuary should not be looked at in isolation of other possible development impacts and other consumptive and non-consumptive uses of the beluga population(s). of the whole of Hudson and James Bay. Monitor traffic on the Nelson River from Conawapa site to the coast to ascertain change in use patterns and intensity. A registry system might be instituted. Monitoring changing resource use patterns that may directly or indirectly expose beluga to some form of exploitation, during construction and operation phases of the project. Tourism, hunting and fishing activities need to be included in the activities monitored.
Related to Tourism Harassment	Research the effect of harassment on movements, distribution and activity of whales in the estuary. This research could be undertaken jointly in cooperation with DFO, DNR and Manitoba Hydro. Deliberate and measured harassment activities would be conducted under controlled conditions. Disturbance studies regarding types of aircraft, time flown over estuary, height while circling etc. to determine effectiveness of present guidelines that were developed for scientific studies. Studies on the time, conditions etc. that influence how long or if whales will habituate to certain types of disturbance. Effects of noise studies. Study and quantify response of beluga to a variety of tourism and industry generated noises. Development of systems for COs and NROs to assist in monitoring activities that may create a disturbance to whales in the estuary. The system developed should be focused on simplicity both in terms of implementing it and in reporting results. (cont.)

Table 10. (cont.) Summary of Working Group 3 discussions related to data requirements and research needed to assess impacts of hydroelecric development at the Conawapa site related to human use aspects of the estuary and their effects on beluga whale.

Subject	Research Initiatives and Data Requirements
Related to Hunting Changing Resource Use Patterns	Research should be conducted to determine the factors that may influence the acceptance and desirability of whale meat/maktak as a country food to non-Inuit aboriginal groups. Whether there are any examples where communities have made shifts in diet should be ascertained. If this research indicates that shifts from river and forest country food to whale meat by non-Iniut aboriginal groups is a possibility, periodic monitoring of local trends in domestic food consumption may be merited. The objective of this monitoring would be to identify any shift in country food diet related to improved access to belugas or because of increased demand for country foods related to increases in non-local native populations. Monitoring human use patterns. Key population areas to serve as indices to use patterns should be monitored with a view to determining what may trigger a change in resource use patterns (change in regulations, change various attributes of the human population, etc.). What are the best indicators of change in use patterns that may have a negative impact on beluga population? When the first whale is killed and arrives in Sundance may be the best "alarm" of a change in resource use trends. Research to understand long-term population trends relative to estuary versus non-estuary occupancy is a must (see biophysical effects group recommendations).
Regulations	Research is required to ascertain what measures may be most effective to control access to and conduct in the estuary in order to minimize the effects on belugas. Are there legal mechanisms currently in place that might be employed more effectively? Trends in aboriginal harvesting rights need to be monitored closely.
Related to Inter-relationship Between Human Use Patterns and Beluga Distribution and Behaviour	Concurrent with monitoring changes in human use patterns, small scale surveys should be done (perhaps employing acoustic monitoring) to detect changes in distribution and abundance of whales in the estuary. A Steering Committee, supported by a Technical Committee, and both comprised of representatives of DFO, DNR, Manitoba Hydro and the resource users, would develop a study framework and ensure coordination of effort between the two monitoring efforts. Monitoring changes in distribution and movement patterns of the beluga will require further development of long-life tags and attachment methods. Success of tagging studies will be improved if, through education and information, hunters were more effectively used to recover tags. Some research with regards to the most effective means of obtaining hunter cooperation may be warranted.
Related to Domestic Fishing	Statistics on changes in commercial and domestic catch and effort may be required to determine whether any increase in fishing intensity as a result of the project are having a negative impact on the beluga.